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# THE LIASSIC AMMONITE ZONES AND SUBZONES OF THE NORTH-WEST EUROPEAN PROVINCE

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CONTENTS

## SYNOPSIS

The paper presents a scheme of ammonite zones and subzones for the Lias of Europe which lies to the north and west of the Alpine belt. It is a revision and amplification of the scheme put forward by Spath in 1942. With a few exceptions selection of the zone and subzone indices is based on priority of usage within the province. Of the 20 zones and 49 subzones used, those newly proposed are the Subzones of *Beaniceras luridum*, *Coroniceras reynesi* and *Schlotheimia extranodosa*. Two main features of the paper are a re-classification of the Hettangian into three zones instead of two as usually accepted, and the replacement of the large and unwieldly Jurense Zone of the Toarcian by three smaller zones ; both result in more balanced arrangements that are more in keeping with the ammonite sequences. Full lists and synonymies are given of all previously proposed Liassic stratal divisions based on ammonites, and the index species of each accepted zone and subzone is figured in the plates.


## I. INTRODUCTION

The Table of Liassic zones and subzones published by Spath (1942) was the first attempt to standardize a set of subzones for the Lias ; the zones into which they were grouped were principally those of Oppel, the originator of Jurassic zoning. The purpose of the present paper is to revise and amplify Spath's scheme after eighteen years of use.

Spath's paper, published in war time, did not include the reason for his selection of indices, although it is clear that he worked on the basis of priority. He had written a " lengthy account of the history and delimitation of the Ammonite zones of the Lias " which was never published. We have tried to remedy the deficiency by giving authors and dates of accepted and rejected zones, and data to assist the recognition of the zones and identification of the index fossils.

In 1942 (p. 267) Spath stated that "... an ideal zonal table should be capable of being used by workers in any part of the world, and only then will lead to a more uniform terminology ". Experience has shown, however, that very few zonal indices have a world-wide distribution, and a more realistic view was taken by Arkell (1946 : 10) : " A stage is an artificial concept transferable to all countries and continents ; but a zone is an empirical unit. If the zone index species and its associated fauna are absent we cannot record the zone ... a zonal table must have specific reference to a particular area ". In spite of Spath's professed views, his Table (unlike that of Muller (1941) which Arkell was criticizing) was founded only on successions in North-west Europe, principally Britain and Germany, although this was not explicitly stated. Donovan (1957 : 147–148, 155–156) has discussed Spath's views on correlation by ammonites.

The revised zonal scheme now presented refers to a particular area : Europe north of and excluding the Alpine belt and the Pyrenees (see Pl. 75). In the Alps and country to the south the system cannot be used on account of the absence

or rarity of many of the index species, apart from the question of the relative time ranges of ammonite species in the two provinces (see Donovan, 1958 : 50). A separate zonal system is necessary there ; this has been worked out for the Toarcian (Donovan, 1958), but for earlier stages stratigraphical information is not yet adequate.

The paper has been written as follows :

Hettangian to Lower Pliensbachian—D. T. D.
Upper Pliensbachian and Toarcian (Whitbian)—M. K. H.
Toarcian (Yeovilian)—W. T. D.

## II. INTERPRETATION OF ZONE AND SUBZONE

The subject and its terminology have been fully discussed by Arkell (1933 : 14–35). There has never been complete agreement as to the interpretation and usage of stratigraphical units, as is shown by the recent exchange of views between Arkell (1956*a*, 1958) and Schindewolf (1957). In the scheme here presented, the units are the subzones, which often correspond to the range of a genus, subgenus or species. For instance, the Raricostatum Subzone corresponds to the range of the genus *Echioceras*, the Conybeari Subzone to that of the subgenus *Metophioceras*, and the Subnodosus Subzone to the range of its index species *Amaltheus subnodosus*. The zones were originally defined by their index species and by other characteristic ammonites ; in most cases these have since been found to be restricted to certain parts of the zone, which is now most satisfactorily defined in terms of the included subzones. It is doubtful whether a single zonal index species in the Lias ranges throughout the whole of the zone to which it gives its name. In some cases zones can be defined in terms of the ranges of genera : the Spinatum Zone corresponds to the range of the genus *Pleuroceras*, and the Angulata Zone to that of *Schlotheimia*. In these cases, the zone can sometimes be recognized when fossils are too poorly preserved or too fragmentary for the subzone to be identified.

## III. PRINCIPLES FOLLOWED IN ZONAL NOMENCLATURE

We have tried to follow the simple rules suggested by Arkell (1946 : 3). We add to these the principle that zonal and subzonal indices should be co-ordinate with one another (in the language of Zoological Nomenclature) ; that is, an index first used for a subzone has priority from this usage if it is upgraded to a zone, and vice versa. Zones are dated from the earliest usage except when this was clearly wrong, when the fact is commented on (see Johnstoni and Scipionianum Subzones).

The only one of Arkell's rules which we feel to be disputable is that dealing with zonal indices which prove to have been misidentified by the original user (rule 4) ; Arkell proposed to use these with their correct names but with priority from the original introduction (with wrong name). This rule could result in the replacement of familiar indices by new names : for instance, Belcheri Subzone (not in fact used)

might be held to have priority over Portlocki Subzone (Lang, 1924), by those who believe that von Schloenbach's Johnstoni Zone (1863) was founded on *Ammonites belcheri* (see pp. 444–445). Such cases are few and we prefer to solve each on its own merits.

The priority rule is qualified in so far as it is restricted to the province for which the Table is intended. For instance, the Marmorea Zone, first used in the eastern Alps (see p. 446) is not considered available, although its index species occurs in North-west Europe. Transference of zones from one province to another will only lead to confusion and is to be avoided.

We have not been able to pursue a consistent policy with regard to the double use of a species as both zonal and subzonal index (Spath, 1942 : 266). Double use is probably better avoided, but a satisfactory alternative cannot always be found. Spath's double use of Angulata disappears as a result of the reclassification of the Hettangian, but Bucklandi and Oxynotum remain in double use, and Raricostatum, Jamesoni, Falcifer and Levesquei are added.

## IV. HEMERAE

Hemerae are briefly mentioned, although by definition they are not synonymous or interchangeable with zones. We do not accept priority of zonal indices from previous use as hemerae, but such use sometimes influenced the naming of zones and not all workers were careful to maintain the distinction between zones and hemerae. The introduction of hemeral indices for the Lias dates from 1898, many of those then published being equivalent to zones as now recognized (Buckman, 1898 : Table facing p. 450). In subsequent works Buckman and other authors employed a large number of additional hemerae. Many are to be found in Buckman (1918 ; 1925), and a table showing Buckman's final scheme will be found in the last volume of *Type Ammonites* (Buckman, 1930 : 37–47). It should be emphasized that the majority of hemerae were hypothetical chronological units and were not defined stratigraphically.

## V. LIMITS OF THE NORTH-WEST EUROPEAN LIASSIC AMMONITE PROVINCE

The extent of the province is shown in Pl. 75, the southern and eastern parts of the boundary being marked by the heavy dashed line. To the south and south-east lies the Mediterranean Liassic Ammonite Province, which includes the outcrops of the Lias in Portugal, Spain, North Africa and Italy, and the Pyrenees and Alpine belt ; knowledge of Lias ammonites from further east is not sufficient to enable the eastern boundary of this province to be determined. The North-west European Province should probably include the Lias outcrops in southern Sweden, for the ammonites appear to belong to north-west European species, but knowledge of their stratigraphical distribution is lacking.

## VI. TABLE OF STAGES, SUBSTAGES, ZONES AND SUBZONES

| Stage | Substage | Zone | Subzone |
|---|---|---|---|
| TOARCIAN | Upper Toarcian or Yeovilian | *Dumortieria levesquei* | *Pleydellia aalensis*<br>*Dumortieria moorei*<br>*Dumortieria levesquei*<br>*Phlyseogrammoceras dispansum* |
| | | *Grammoceras thouarsense* | *Pseudogrammoceras struckmanni*<br>*Grammoceras striatulum* |
| | | *Haugia variabilis* | |
| | Lower Toarcian or Whitbian | *Hildoceras bifrons* | *Zugodactylites braunianus*<br>*Peronoceras fibulatum*<br>*Dactylioceras commune* |
| | | *Harpoceras falcifer* | *Harpoceras falcifer*<br>*Harpoceras exaratum* |
| | | *Dactylioceras tenuicostatum* | |
| PLIENSBACHIAN | Upper Pliensbachian or Domerian | *Pleuroceras spinatum* | *Pleuroceras hawskerense*<br>*Pleuroceras apyrenum* |
| | | *Amaltheus margaritatus* | *Amaltheus gibbosus*<br>*Amaltheus subnodosus*<br>*Amaltheus stokesi* |
| | Lower Pliensbachian or Carixian | *Prodactylioceras davoei* | *Oistoceras figulinum*<br>*Androgynoceras capricornus*<br>*Androgynoceras maculatum* |
| | | *Tragophylloceras ibex* | *Beaniceras luridum*<br>*Acanthopleuroceras valdani*<br>*Tropidoceras masseanum* |
| | | *Uptonia jamesoni* | *Uptonia jamesoni*<br>*Platypleuroceras brevispina*<br>*Polymorphites polymorphus*<br>*Phricodoceras taylori* |
| SINEMURIAN | Upper Sinemurian | *Echioceras raricostatum* | *Paltechioceras aplanatum*<br>*Leptechioceras macdonnelli*<br>*Echioceras raricostatum*<br>*Crucilobiceras densinodulum* |
| | | *Oxynoticeras oxynotum* | *Oxynoticeras oxynotum*<br>*Oxynoticeras simpsoni* |
| | | *Asteroceras obtusum* | *Eparietites denotatus*<br>*Asteroceras stellare*<br>*Asteroceras obtusum* |
| | Lower Sinemurian | *Caenisites turneri* | *Microderoceras birchi*<br>*Caenisites brooki* |
| | | *Arnioceras semicostatum* | *Euagassiceras sauzeanum*<br>*Agassiceras scipionianum*<br>*Coroniceras reynesi* |
| | | *Arietites bucklandi* | *Arietites bucklandi*<br>*Coroniceras rotiforme*<br>*Coroniceras* (*Metophioceras*) *conybeari* |

| Stage | Substage | Zone | Subzone |
|---|---|---|---|
| HETTANGIAN | — | *Schlotheimia angulata* | *Schlotheimia complanata*<br>*Schlotheimia extranodosa* |
| | | *Alsatites liasicus* | *Alsatites laqueus*<br>*Schlotheimia* (*Waehneroceras*) *portlocki* |
| | | *Psiloceras planorbis* | *Psiloceras* (*Caloceras*) *johnstoni*<br>*Psiloceras planorbis* |

## VII. THE STAGES, ZONES AND SUBZONES

Under the heading INDEX SPECIES references are given to the original description, and to authors who have refigured or revised the species. An example of the index species to each zone and subzone is figured in the plates, in many cases from type material.

The heading NOMENCLATURE refers to stratigraphical nomenclature; here the first use of each unit is stated, followed by subsequent changes in meaning, and synonyms.

Under the heading STRATIGRAPHY criteria useful for recognizing the unit are noted, together with brief details of its development and geographical extent.

### HETTANGIAN STAGE

This stage was introduced by Renevier (1864 : 86) for Oppel's Planorbis and Angulata Zones. At the type-locality of Hettange (Moselle), France, ammonites are rare in the Grès d'Hettange but this formation is overlain by limestones and shales containing early Bucklandi Zone ammonites and it may therefore be correlated with the Hettangian Stage as usually understood.

The term Infralias, first used by Leymerie (1838 : 376) in a sense equivalent to Hettangian, later became extended to include rocks of Rhaetian age below. The rejection of the term Infralias was favoured by Renevier when he proposed the Hettangian Stage.

Buckman's Caloceratan Age (1898 : 446) was defined as " time of Hettangian Stage ". It was later replaced (1925) by Psiloceratan and Schlotheimian Ages.

Spath (1942) retained Oppel's two zones, each with two subzones, as follows, and indicated a number of horizons said to be of local value :

| Zones | Subzones | Horizons |
|---|---|---|
| *Scamnoceras angulatum* | *Scamnoceras angulatum* (s.s.) | *Schlotheimia complanata*<br>*S. lymense*<br>*S. phoenix* |
| | *Alsatites laqueus* | *Saxoceras gallicum*<br>*S. prometheus*<br>*Psilophyllites hagenowi* |
| *Psiloceras planorbis* | *Caloceras johnstoni* | *Waehneroceras portlocki*<br>*C. johnstoni* (s.s.) |
| | *P. planorbis* (s.s.) | |

This scheme is unsatisfactory for several reasons: the subzone of *C. johnstoni* includes the horizon of *W. portlocki*, but a series of faunas dominated by *Waehneroceras* continues into the subzone of *A. laqueus*. The zone of *S. angulatum* is extended downwards to include the latter subzone. Both the zones are unwieldy.

A more balanced scheme comprises three zones, giving separate recognition to the *Waehneroceras-Alsatites* faunas. The Planorbis Zone will then correspond nearly to the range of *Psiloceras* and the Angulata Zone to that of *Schlotheimia*. This arrangement was first employed by Collenot (1869 : 64), and adopted by Haug (1910 : 954) and many other continental authors.

## PLANORBIS ZONE

(Pl. 63, fig. 1)

INDEX SPECIES. *Psiloceras planorbis* (J. de C. Sowerby, 1824 : 69, pl. 448). Lectotype designated and figured by Arkell (1956 : 760, pl. 31, fig. 7).

NOMENCLATURE. First used by Oppel (1856 : 24). Synonyms: Burgundiae Zone (Zone à *Amm. Burgundiae*) of Martin (1860 : 28); Psilonotus Zone (Vaughan & Tutcher, 1903 : 10, 12, 14).

STRATIGRAPHY. Oppel cited *Ammonites planorbis* and *Ammonites johnstoni* J. de C. Sowerby as guide fossils for the zone, and it has since been found that they characterize successive levels throughout the province. The zone is therefore divided into two subzones on this basis.

### *Planorbis Subzone*

(Pl. 63, fig. 1)

INDEX SPECIES. As for Planorbis Zone.

NOMENCLATURE. See Planorbis Zone. A subzone of Planorbis *s.s.* was first employed by Trueman (1922 : 251). The Psilonotum Zone as used by North German authors is equivalent to Planorbis Subzone. Includes the *planorbis*, *aequabile*, *erugatum*, *psilonotus* and *plicatus* hemerae (Buckman, 1930 : 47).

STRATIGRAPHY. Subdivision of this part of the sequence has not been convincingly accomplished and Buckman's five hemerae (see above) are at least partly hypothetical (Donovan, 1952 : 635). There is evidence for distinguishing a lower horizon with smooth species of *Psiloceras* s.s. (*P. planorbis*, *P. psilonotum* (Quenstedt)) from an upper with plicate ones (*P. plicatulum* (Quenstedt)) near Bristol, England (Donovan, 1952 : 634), and in the Psilonotenbank of South Germany (Frank, 1931 : 11); this sequence is not yet proved to be generally valid. The subzone is almost universally present throughout the province, but is said to be absent in the Pfälz area of westernmost Germany (Jüngst, 1938 : 154).

In Britain there are in many areas a few feet of strata without ammonites at the base of the Blue Lias, underlying rocks with the Planorbis Subzone fauna. The name Pre-Planorbis Beds has often been applied to them, and species of lamellibranchs have been used as zonal indices, viz. *Ostrea liassica* Strickland and *Pteromya crow-*

*combeia* Moore, the latter superseded by *Pleuromya tatei* Richardson & Tutcher. Details will be found in the forthcoming Jurassic section of the Lexique Stratigraphique International for Britain.

Donovan (1956 : 198) pointed out that the first appearance of ammonites does not necessarily mark a constant horizon and proposed that the Planorbis Subzone be extended downwards to include the old " pre-Planorbis Beds ", the lamellibranch zones being retained, for local use only, if needed.

### *Johnstoni Subzone*

(Pl. 63, fig. 2)

INDEX SPECIES. *Psiloceras* (*Caloceras*) *johnstoni* (J. de C. Sowerby, 1824 : 70, pl. 449, fig. 1).

NOMENCLATURE. A zone of *Ammonites johnstoni* was first used by von Schloenbach (1863 : 498), as the equivalent in North Germany of the Planorbis Zone, but later research has shown that the ammonites previously known as *Caloceras johnstoni* in North Germany do not belong to that species (Hoffmann, 1949 : 114).[1]

According to Arkell's proposed rules (1946 : 3, Rule 4) this should become the Belcheri Zone with priority from von Schloenbach. The Johnstoni Subzone as correctly used may be taken to date from Stoddart (1868 : 201 : Johnstoni-beds) or Tutcher (1918 : 279 : Johnstoni Zone). It was made the upper subzone of the Planorbis Zone by Trueman (1922 : 251). It is equivalent to Buckman's *johnstoni* hemera (1930 : 47).

STRATIGRAPHY. The base of the subzone is marked by the appearance of *Caloceras*, *P.* (*C*). *johnstoni* being probably the earliest species. The genus ranges up into the Portlocki Subzone with species such as *P.* (*C*). *belcheri* (Simpson) and *P.* (*C.*) *bloomfieldense* Donovan. The top of the subzone is taken at the appearance of *Waehneroceras*. The subzone as here understood is smaller than the Johnstoni Subzone of Spath (1942), which included the strata here separated as the Portlocki Subzone. The subzone is absent or unproved in North Germany, as remarked above, but is present in Britain and France. The index fossil is recorded from South Germany but this identification awaits confirmation.

## LIASICUS ZONE

(Pl. 63, fig. 3)

INDEX SPECIES. *Alsatites liasicus* (d'Orbigny, 1844 : 199, pl. 48). The lectotype was designated by Donovan (1952 : 644) and figured by Reynès (1879, pl. 6, figs. 9–12).

NOMENCLATURE. First used by Collenot (1869 : 64) who inserted it between the Planorbis and Angulata Zones. It has priority over Laqueus Zone (Reynès, 1879),

[1] Lange (1941) and Hoffmann (1949) identify them as *C. torus* (d'Orbigny) ; in the present writer's view they are *C. belcheri* Simpson (see Donovan, 1952 : 637).

here retained as a subzone. Spath was evidently unaware of the earlier publication of Liasicus, for he believed (unpublished MS.) Laqueus to have priority. *Alsatites laqueolus* (Schloenbach), used as a zonal index by Hoffmann (1949 : 114), is a synonym of *A. liasicus* (see Donovan, 1952 : 644). The Catenatum Subzone provisionally proposed by Quilter (1886 : 65) is also a synonym of Liasicus Zone.

Stratigraphy. The zone is best defined in terms of its two subzones, for the range of *Alsatites liasicus* is not well established. The more detailed subdivision of the lower part, which has been used in some areas, is reviewed under the Portlocki Subzone. Lang's (1924 : 181) Zone of *Alsatites liasicus* on the Dorset coast is a much smaller unit which falls at the top of the zone as it is here understood.

### *Portlocki Subzone*

(Pl. 63, fig. 4)

Index species. *Schlotheimia* (*Waehneroceras*) *portlocki* (Wright, 1881, pl. 48, figs. 4, 5). See Donovan (1952 : 646).

Nomenclature. Introduced by Lang (1924 : 172, 182), in a more restricted sense than now used. For general use the subzone includes the Hagenowi Zone of Lang (1924), and the Torus, Schroederi and Angersbachense Zones of Lange (1931 : 352) although these may be useful for local successions (see below). The Megastoma Zone of Waehner (1886 : 169) is a senior synonym even if accepted only from its adoption for the British sequence by Buckman (1910*a* : xvi). It was proposed, however, for the east-Alpine area and is not considered available for the province now under consideration.

The Longipontinus Zone of Oppel (1862 : 92 ; 1863 : 131) was proposed as a substitute for the Planorbis and Angulata Zones together. If restricted to the range of the index species, *Schlotheimia* (*Waehneroceras*) *longipontina* (Oppel), it might be held to be a prior name for Portlocki Subzone. It is not now adopted because it has not been employed since its introduction, and the index species has not been commonly recorded from the province.

Includes the *portlocki* and *hagenowi* hemerae of Buckman (1930 : 47).

Stratigraphy. The base of the subzone is taken at the first appearance of *Waehneroceras*. *Alsatites* may first appear in the subzone in some areas. Locally the beds included in the subzone have been further divided, as many as four subdivisions being recognized in North Germany (Lange, 1931 : 352, α 1b–e). The lowest is the *torus* horizon (*recte* Belcheri " Zone ", see above) which has not been recorded elsewhere, but is presumably represented by the beds which yield *Psiloceras* (*Caloceras*) *belcheri* (Simpson) in Yorkshire ; their stratigraphy is inadequately known. The next, the *hagenowi* horizon, has been identified at a number of places : the Pfälz area of western Germany (Jüngst, 1938, fig. 3) ; south-western Germany (Frank, 1931 : 14, etc.) ; Dorset, England (Lang, 1924 : 182) ; and Glamorgan, Wales (Trueman, 1920). It is not certain, however, whether all these occurrences lie at a constant horizon, and on account of this fact, the sporadic occurrence of the

index species, and the difficulty of identifying it[1] (possibly a reason for the apparently sporadic distribution) the horizon is not adopted for general use. The two highest subdivisions are said to be characterized by *Saxoceras schroederi* Lange and S. *angersbachense* Lange, which, in the present writer's opinion, are species of *Waehneroceras* allied to *W. portlocki*. In most areas the fossil material is not good enough for the sequence of *Waehneroceras* species to be elucidated, and so these horizons cannot be used generally.

### *Laqueus Subzone*

(Pl. 63, fig. 5)

INDEX SPECIES. *Alsatites laqueus* (Quenstedt, 1856 : 43, pl. 3, fig. 5). See Donovan (1952 : 642).

NOMENCLATURE. First used in the explanations to plates 2 and 3 of Reynès' Atlas (1879). Spath (1942) adopted the index for the lower subzone of his Angulata Zone. Lange's Costatum Zone (1931 : 352) is a synonym. Buckman's *gallica, prometheus, laqueus* and *megastoma* hemerae correspond to the subzone (1930 : 47).

STRATIGRAPHY. The subzone is recognizable throughout the province. *Waehneroceras* may range up into it, and the boundary with the Portlocki Subzone is taken at the first appearance of the index species or of the genus *Saxoceras* which is characteristic of the subzone.

## ANGULATA ZONE

(Pl. 64, fig. 5)

INDEX SPECIES. *Schlotheimia angulata* (Schlotheim, 1820 : 70). Lectotype designated and figured by Lange (1951 : 33, pl. 1, fig. 2).

NOMENCLATURE. First used by Oppel (1856 : 28). The Marmorea Zone of Waehner (1886 : 169–170), used by Buckman as a hemera (1898, Table facing p. 450), and as a zone (1910*a* : xvi), is a synonym as far as the present province is concerned, although a valid zone for the east Alpine area ; the index species is a *Charmasseiceras* (Donovan, 1952 : 653) and is not confined to the Angulata Zone. The Moreanus Zone of Martin (1860 : 38) is a synonym, and was said by Martin to be the equivalent of the Angulata Zone.

Buckman's *acuticosta, angulata, marmorea* and *phoenix* hemerae correspond to the zone (1930 : 47).

STRATIGRAPHY. The base of the zone is marked by the incoming of *Schlotheimia* (s.s.), and the top by the appearance of *Coroniceras* (*Metophioceras*). The latter horizon may not be constant but a better criterion cannot be suggested at present. The zone as now interpreted is equivalent to Angulata Subzone of Spath (1942). It is not easy to recognize subzones of general usefulness. Three are recognized in North Germany, but only two are provisionally adopted here.

[1] *Psilophyllites hagenowi* has the same shell-form as *Psiloceras*, and is distinguished only by the septal suture. There are transitional species ("*Neophyllites*" of Lange, 1941).

*Extranodosa Subzone*

(Pl. 64, fig. 1)

INDEX SPECIES. *Schlotheimia extranodosa* (Waehner, 1886 : 168, pl. 20, figs. 10, 11). See Donovan (1952 : 651).

NOMENCLATURE. The name replaces Germanica Zone of Lange (1922 : 461–462) whose index species was a *nomen nudum* when the zone was introduced, and on description (Lange, 1924 : 201 ; 1951 : 69, pl. 8, fig. 11) proved to be synonymous with *S. extranodosa* (Donovan, 1952).

STRATIGRAPHY. The subzone is well developed in North Germany, and is represented in southern England by the index species (Donovan, 1956 : 186). The sucession within the Angulata Zone in France is insufficiently known. In North Germany a zone of *Schlotheimia amblygonia* Lange is recognized below the Extranodosa (" Germanica ") Subzone, within the Angulata Zone ; it has not been distinguished elsewhere.

*Complanata Subzone*

(Pl. 64, fig. 2)

INDEX SPECIES. *Schlotheimia complanata* von Koenen (1902 : 9, pl. 7, figs. 4–6). Type refigured by Lange (1925, pl. 21, figs. 5*a*, *b*).

NOMENCLATURE. The name replaces Stenorhyncha Zone of Lange (1922 : 461, 463). When first used the index species *Schlotheimia stenorhyncha* was a *nomen nudum*, but it was described by Lange (1924 : 202) and figured in 1951 (pl. 15, figs. 1*a*, *b*). Spath (1942 : 267) suggested a *complanata* horizon to replace Lange's *stenorhyncha*, then still unfigured. In the present writer's view the two species are synonyms.

STRATIGRAPHY. This subzone forms the highest subdivision of the Angulata Zone in North Germany but is only locally developed (Lange, 1922 : 463). In southern England the subzone is represented by beds with *Schlotheimia similis* Spath, closely related to the index species, in Dorset (Lang, 1924 : 181) and Somerset (Donovan, 1956 : 201, etc.). In southern England the beds with *S. similis* are succeeded by strata with giant species (*S. pseudomoreana* Spath) but palaeontological data are inadequate, and the beds have not been traced elsewhere, although they may be represented by Jüngst's (1938 : 154, 163) " Unnamed zone " with large Schlotheimiidae above the " Stenorhyncha " Zone in the Pfälz area of western Germany.

## SINEMURIAN STAGE

The division into zones is unchanged from that of Spath (1942), with a few changes to subzones and consequent slight alterations in zonal boundaries. The zones date from Oppel, except that the upper part of his Bucklandi Zone has been separated as the Semicostatum Zone, and his zone of *Pentacrinus tuberculatus* has been replaced by an ammonite zone, the Turneri Zone. The division into Lower and Upper Sinemurian was first made by Oppel (1856 : 59) who spoke of Obtusum, Oxynotum and Raricostatum Zones as constituting the Upper Sinemurian.

The Lotharingian Stage of Haug (1910 : 948) was used for the Turneri (also called Birchi, p. 964), Obtusum, Oxynotum and Raricostatum Zones, the last two being used as alternatives by Haug. Lotharingian was erroneously equated with Upper Sinemurian in Oppel's sense by Spath (1942). Certain French authors have used the Lower Sinemurian for the Bucklandi and Semicostatum Zones only, thus making the Upper Sinemurian larger and equivalent to Lotharingian (e.g. Gignoux, 1950 : 352), while others (e.g. Abrard, 1948 : 12) follow Haug (1910) in restricting Sinemurian to these two zones. Buckman (1910*a* : xvi) excluded the Raricostatum Zone from the Sinemurian and placed it at the base of the Charmouthian Stage.

The Sinemurian as here understood includes four stages introduced by Buckman (1917 ; 1918 : 267–275) : Lymian, Mercian, Deiran and Raasayan. Having been defined in terms of a hypothetical hemeral system their limits are not well established. Lymian corresponds to the Bucklandi and Semicostatum Zones, but includes a *birchi* hemera at the top. Since the *brooki* and *turneri* hemerae were excluded it cannot be synonymous with Lower Sinemurian, although it was so equated by Spath (1942 : 265). Mercian corresponds approximately to the Turneri and Obtusum Zones, and Raasayan includes the Raricostatum Zone. These terms are not adopted in this paper.

The Sinemurian from the base up to the Oxynotum Zone inclusive corresponds to the Asteroceratan Age of Buckman (1898 : 447), later restricted by the separation of Vermiceratan, Coroniceratan, Agassiceratan, Microderoceratan and Oxynoticeratan Ages. Buckman's Deroceratan Age, as later restricted, corresponds approximately to the Raricostatum Zone but includes the base of the Jamesoni Zone.

## BUCKLANDI ZONE

(Pl. 64, fig. 3)

INDEX SPECIES. *Arietites bucklandi* (J. Sowerby, 1816 : 69, pl. 130). See Donovan (1952 : 718). The neotype was figured by Arkell (1956, pl. 31, fig. 4).

NOMENCLATURE. Introduced by Oppel (1856 : 35), and later restricted by the proposal of the Semicostatum Zone (see p. 451).

STRATIGRAPHY. The two lower subzones reflect an evolutionary trend in the genus *Coroniceras* and are well established, but stratigraphy of the upper part of the zone is less satisfactory. *Vermiceras scylla* (Reynès) is found in the Conybeari and Rotiforme Subzones, and the Schlotheimiidae *Charmasseiceras* occurs throughout the zone.

### *Conybeari Subzone*

(Pl. 64, fig. 4)

INDEX SPECIES. *Coroniceras* (*Metophioceras*) *conybeari* (J. Sowerby, 1816 : 70, pl. 131). See Donovan (1952 : 728).

NOMENCLATURE. First used, as a zone, by Tutcher (1918 : 279). Trueman (1922 : 251) placed it as the lowest subzone of the Bucklandi Zone. Spath (1924 : 187) included in the Conybeari Zone two hemerae, *longidomus* and *brevidorsale*, on the

basis of records of these species from Württemburg. Hoffmann (1949 : 114) adopted *Vermiceras longidomus* as a zonal index for the lowest zone of the Sinemurian, and as *Coroniceras* (*Metophioceras*) *longidomum* (Quenstedt) the index was used for south-western Germany by Walliser (1956 : 217). Longidomum Zone is a synonym of Conybeari Subzone as here used.

The subzone includes the *longidomus*, *brevidorsale* and *scylla* hemerae (Buckman, 1930 : 47). The *charmassei* hemera was placed by Buckman (1925 : 78) above his *bucklandi* hemera, but it probably falls in this or in the next subzone.

Stratigraphy. There is general agreement that the appearance of the subgenus *Metophioceras* marks the base of the Sinemurian. It has been recorded throughout the province, with the exception of north-western Germany, where there is a non-sequence at this level (Hoffmann, 1949 : 114). Further subdivision does not seem practical. Spath's hemerae mentioned above were adopted by Muller (1941, Table 2) as subdivisions, of unspecified rank, of the Conybeari Subzone. According to Walliser (1956 : 197, 216), who states that the two species are closely allied, their ranges overlap, but *Coroniceras* (*Metophioceras*) *longidomum* (Quenstedt) appears first and *C.* (*M.*) *brevidorsale* (Quenstedt) survives later. There is no evidence yet that this succession is of more than local importance.

### *Rotiforme Subzone*

(Pl. 65, fig. 2)

Index species. *Coroniceras rotiforme* (J. de C. Sowerby, 1824 : 76, pl. 453). See Donovan (1952 : 730).

Nomenclature. *Ammonites rotiformis* was first used as a zonal index by Collenot (1879 : 790), replacing his earlier and incorrect use of *Am. scipionianus* above Angulatus and below Bucklandi (1869 : 132). Trueman (1922 : 251) reduced the zone to the status of a subzone of the Bucklandi Zone. Fiege (1926 : 210) spoke of a " Zone of *Arietites Schloenbachi* " which is probably synonymous with Rotiforme Subzone. He stated that *Coroniceras westfalicum* Lange was identical with *C. schloenbachi* (Reynès), but later Hoffmann (1949 : 114) employed these two species as indices for successive zones, presumably with special reference to Germany. The subzone includes the *kridion*, *rotator* and *schloenbachi* hemerae (Buckman, 1925 : 78 ; 1930 : 47).

Stratigraphy. The subzone succeeds the Conybeari Subzone throughout the province, the lower boundary being marked by the incoming of *Coroniceras* (s.s.). The upper boundary is not so satisfactory, but is conveniently drawn immediately below the appearance of large ammonites of the genera *Arietites* and *Pararnioceras* : the matter is discussed below (Bucklandi Subzone). Locally the subzone can be divided but it does not seem possible to correlate the subdivisions in England and Germany. In southern England *Coroniceras rotiforme* and allied species, such as *C. schloenbachi* (Reynès), are confined to the lower part of the subzone, while the upper part is characterized by *Coroniceras caprotinum* (d'Orbigny) and *C. hyatti* Donovan,[1] as demonstrated by Donovan (1956 : 207, 210–211) and confirmed by the

[1] This group is referred to as *Arnioceratoides* in the publications of Spath and Trueman.

Stowell Park Borehole (Spath, 1956 : 157). In Germany *Coroniceras westfalicum* is stated to be earlier than *C. schloenbachi*, as noted above, but a separate *C. caprotinum* horizon has not been distinguished. *Coroniceras caprotinum* is found in Württemberg, as shown by the series of examples from Vaihingen figured by Reynès (see Donovan, 1955 : 27). The latest work on the South-west German Lias (Walliser, 1956) does not distinguish any subdivisions of the Rotiforme Subzone. In France, in the type area of the Sinemurian (the Semur area, Côte d'Or), the horizon with *C. rotiforme* is succeeded by one characterized by *C. kridion*,[1] recalling the succession in southern England. The *C. kridion* fauna is already accompanied by *Pararnioceras meridionale* (Reynès) (Mouterde, 1953 : 396).

### *Bucklandi Subzone*

(Pl. 64, fig. 3)

INDEX SPECIES. See Bucklandi Zone.

NOMENCLATURE. See Bucklandi Zone. After the separation of the Semicostatum Zone, the zone was further restricted by the introduction of the Rotiforme Zone. In 1942 Spath reduced this restricted zone to the status of a subzone of the Bucklandi Zone.

The subzone includes the *bucklandi* hemera of Buckman (1930 : 46) and probably the *charmassei* hemera of Spath (1924).

STRATIGRAPHY. It is often difficult to delimit the subzone for the index species is seldom common, and has often been misinterpreted. Like *Pararnioceras meridionale* (Reynès), which also occurs in the subzone, it is a large ammonite and is rarely collected *in situ*. Its stratigraphical position has been confirmed in the Bristol Region (Donovan, 1956 : 203). Certainly in Britain, and probably throughout the province, *Arietites bucklandi*[2] is not a good subzonal index fossil, but nothing better can yet be suggested. There should be no hesitation in abandoning it if a better species is forthcoming.

In the Stowell Park Borehole Spath (1956 : 160) noted three distinct divisions of the subzone, but they cannot be correlated with sections elsewhere. The ammonites referred by Spath to his genus *Epammonites* (probably merely closely ribbed species of *Coroniceras* (*Primarietites*)) are found in the subzone. The remaining noteworthy feature of the subzone is the first appearance of the genus *Arnioceras*.

## SEMICOSTATUM ZONE

(Pl. 65, fig. 4)

INDEX SPECIES. *Arnioceras semicostatum* (Young & Bird, 1828 : 257, 359). The holotype was refigured by Buckman (1918*a*, pl. 112) and again by Jaworski (1931, pl. 5, figs. 1*a*, *b*).

[1] *Coroniceras kridion* (Hehl MS. *in* Zieten), the type of which has recently been refigured by Walliser (1956, pl. 10, fig. 5) is apparently the inner whorls of a species of the *hyatti-caprotinum* group. It is not the inner whorls of *C. rotiforme*.

[2] As properly restricted ; in the past it was often used as all-embracing name for large, bisulcate arietitids.

NOMENCLATURE. The zone was proposed by Judd (1875 : 42) to replace the Geometricus Zone used by Oppel for the upper part of his comprehensive Bucklandi Zone. Oppel's *Ammonites geometricus* (1856 : 79) was a homonym of *Ammonites geometricus* Phillips (1829), and as such was rejected by Spath (1942 : 266) as a zonal index. Lang's Arnioceras Zone (1914 : 312) is a synonym.

STRATIGRAPHY. The existing subzones, adopted by Spath (1942) from Tutcher (1918), are retained except that Gmuendense is replaced by Reynesi Subzone (see below). The genus *Arnioceras* itself is of little stratigraphical use : it has a long range, up to a horizon high in the Obtusum Zone, and although Spath (1956 : 161) has given a succession of species, the fact remains that species from the Obtusum Zone (e.g. *A. semicostatoides* Spath) are barely distinguishable from *A. semicostatum*, unless exceptionally well-preserved material is available (Spath, 1956 : 151). The zone is retained, in default of a better alternative, but the presence of the index fossil, without supporting ammonites, cannot be taken as positive evidence for its identification.

In consequence of the abandonment of the Alcinoë Subzone the boundary between the Semicostatum and Turneri Zones is placed higher than by Spath (1942), at the incoming of *Caenisites* instead of at the disappearance of *Euagassiceras*.

### *Reynesi Subzone*

(Pl. 65, fig. 5)

INDEX SPECIES. *Coroniceras reynesi* (Spath, 1923 : 72). Lectotype figured by Reynès (1879, pl. 24, figs. 27, 28) and designated by Donovan (1952 : 738).

NOMENCLATURE. The subzone is here proposed to replace the Gmuendense Zone introduced by Buckman (1910*a* : xvi), and adopted by Spath (1942) as the lowest subzone of the Semicostatum Zone. *Ammonites gmuendensis* Oppel was described but never figured by its author, and Prof. Dehm, of Munich, informs me (*in litt.*) that no type material can now be recognized. Numerous figures purporting to represent the species have been published but they include several species, and Spath's selection (1922 : 173) of Reynès' figures was irregular. As the species cannot be defined it cannot be used as a zonal index.

The *gmuendense, meridionalis* and *vercingetorix* hemerae (Buckman, 1918 : 274 ; 1930 : 46) fall in the subzone

STRATIGRAPHY. In Somerset *Coroniceras reynesi* is abundant in the beds above the Bucklandi Subzone, which also yield occasional examples of *Paracoroniceras*, that is, species related to *C. reynesi* in which the outer whorl acquires a trigonal section. The species occurs in Germany (the syntypes ; compare also the ammonites figured by Fiege (1929) as *Arietites bucklandi*) but precise stratigraphical information is lacking. In France data are also insufficient ; it is possible that Mouterde's horizon of *Arnioceras ceratitoides* (1953 : 396–397) represents this subzone.

### *Scipionianum Subzone*

(Pl. 65, fig. 3)

INDEX SPECIES. *Agassiceras scipionianum* (d'Orbigny, 1844 : 207, pl. 51, figs. 7–8). See Donovan (1952 : 745).

NOMENCLATURE. The subzone as correctly understood dates from Tutcher (1918 : 279) who used it as a zone, but it was reduced to the status of a subzone by Trueman (1922 : 251). A zone of *Ammonites scipionianus* had been used by Collenot (1869 : 132), but he placed it too low, between his Angulatus and Bucklandi Zones. Junior synonyms are the Pseudokridion Zone (Lang, 1924 : 176), Acuticarinatum Zone (Spath, 1924 : 186), and Colesi Subzone (Muller, 1941, Table 2). The subzone includes the *Agassiceras* hemera of Buckman (1918 : 274), and the *acuticarinatum*, *colesi* and *pseudokridion* hemerae of Spath (1924 : 187).

STRATIGRAPHY. Besides the index species the subzone is characterized by *Arnioceras acuticarinatum* (Simpson) and the genus *Metarnioceras*. On the Dorset coast and in the Stowell Park Borehole *M. pseudokridion* Spath occurs just above *A. scipionanum* and Lang (1924 : 176) recognized a separate Pseudokridion Zone. This may be useful for southern England but confirmation of its general validity is lacking. In Auxois *Metarnioceras pellati* (Dumortier) is recorded above *Euagassiceras sauzeanum* (Mouterde, 1953 : 227). The subzone is present throughout the province ; in Württemberg, according to Walliser (1956 : 216) *Paracoroniceras* ("*Arietites gmuendensis*") survives into it, and the index fossil is accompanied by the large *Agassiceras nodosaries* (Quenstedt).

### *Sauzeanum Subzone*

(Pl. 65, fig. 1)

INDEX SPECIES. *Euagassiceras sauzeanum* (d'Orbigny, 1844 : 304, pl. 95, figs. 4, 5). D'Orbigny's figured specimen was refigured by Hyatt (1889, pl. 6, figs. 12, 13). The index species is probably a synonym of *E. resupinatum* (Simpson, 1843 : 15) but not figured until much later (Buckman, 1909, pl. 6). See Donovan (1952 : 742),

NOMENCLATURE. The Sauzeanum Zone of Tutcher (1918 : 279) was reduced to the status of a subzone of the Bucklandi Zone by Trueman (1922 : 251) and transferred to the Semicostatum Zone by Spath (1942). It is now extended to include the Alcinoë Subzone of Muller (1941, Table 2) (see below), and also embraces Muller's Striaries and Gaudryi Subzones. It includes the *alcinoë*, *Euagassiceras*, *sauzeanum* and *striaries* hemerae of Spath (1924 : 187) and Buckman (1930 : 46).

STRATIGRAPHY. The subzone is recognized throughout the province. It is characterized by various species of *Euagassiceras* but some of these, although not, apparently, *E. sauzeanum* itself, first appear in the Scipionianum Subzone.[1]

In 1942 Spath adopted the Alcinoë Subzone from Muller (1941), who derived it from the *Pararnioceras alcinoë* Bed in Dorset (Lang, 1923 : 61). Since the horizon

[1] Walliser's Table (1956 : 216) shows *sauzeanum* appearing in the succession before *scipionianum* ; but reference to p. 202 of his paper shows that he includes in *E. sauzeanum* the species *E. spinaries* (Quenstedt) which is present in the Scipionianum Subzone in Dorset. See also Hallam (1960 : 3, 4).

of this fossil has not been recognized elsewhere, except in the Stowell Park Borehole, it is discarded as a subzonal index. The *P. alcinoë* horizon in southern England is now included in the Sauzeanum Subzone, for *Euagassiceras* persists into it in Dorset.

## TURNERI ZONE

(Pl. 66, fig. 2)

INDEX SPECIES. *Caenisites turneri* (J. de C. Sowerby, 1824 : 75, pl. 452). The lectotype was designated by Buckman (1898 : 453) and refigured by Wright (1879, pl. 12, fig. 4).

NOMENCLATURE. The zone was introduced by Wright (1860 : 403) to replace Oppel's Zone of *Pentacrinus tuberculatus*. Muller (1941, Table 2), who applied the name Semicostatum Zone to this part of the sequence (see Spath, 1942), divided it into Alcinoë, Nodulosum, Sulcifer, Brooki, Hartmanni and Birchi Subzones. It is difficult to place these in the synonymy of the subzones now accepted, since they were derived from Buckman's hemerae (1930 : 46) of the same names, the order of which was hypothetical. Buckman's *ploti*, *inflatum*, *turneri* and *turgescens* hemerae also fall within the zone (1930 : 45, 46).

STRATIGRAPHY. The zone is now divided into two subzones only, Spath's Alcinoë Subzone at the base having been incorporated in the Sauzeanum Subzone (see above). The subzones are not widely applicable and may have to be abandoned or replaced. A subzonal scheme founded on species either of *Microderoceras* or of *Caenisites* alone would be preferable, but does not seem to be feasible on present evidence.

### *Brooki Subzone*

(Pl. 66, fig. 1)

INDEX SPECIES. *Caenisites brooki* (J. Sowerby, 1818 : 203, pl. 190).

NOMENCLATURE. The subzone was introduced by Lang (1914 : 317) as a subdivision of Oppel's Obtusum Zone in the Dorset coast succession, but the stratigraphical position of the index species was misunderstood. This was rectified later (Lang, 1923) and the subzone transferred to the Turneri Zone by Spath (1942).

STRATIGRAPHY. In Dorset the index species is restricted to one three-inch bed (Lang, 1923 : 59) and the only satisfactory way to define the subzone is by additional species of *Caenisites*. The base of the subzone is characterized by *C. preplotti* Spath and *C. costariformis* Spath and the top by *C. brooki*. There seem to be no good supporting species of other genera. In Dorset "*Sulciferites*" is restricted to the lower part of the subzone, but in the Stowell Park Borehole it was found in the Birchi Subzone (Spath, 1956 : 152) ; as the "genus" differs from *Charmasseiceras* of the Bucklandi Zone merely by its later date, examples may be expected at intermediate horizons. In view of these considerations and of the difficulty of distinguishing between species of *Caenisites* the subzone is not a satisfactory one, and it has not been generally recognized on the Continent. It is retained in the hope that further

evidence as to the position of *Caenisites*, and the appearance of *Microderoceras* in continental countries, may be forthcoming.

### *Birchi Subzone*

(Pl. 66, fig. 3)

INDEX SPECIES. *Microderoceras birchi* (J. Sowerby, 1820 : 121, pl. 267).

NOMENCLATURE. The zone was first used by Collenot (1869 : 132) for the Auxois district of France, and has been generally adopted. Spath (1942) used it as a subzone of the Turneri Zone. The Capricornoides Zone of Lang (1936 : 160) is a synonym.

STRATIGRAPHY. The range of the index species at its type locality, on the Dorset coast, is small (Lang, 1923 : 57–58), but the subzone has been generally interpreted as corresponding to the vertical range of *Microderoceras*. *Caenisites* persists into the subzone, while the upper part is characterized by *Promicroceras capricornoides* (Quenstedt). The top of the subzone is taken at the appearance of the genus *Asteroceras* at the base of the Obtusum Zone. The Capricornoides Zone in northern Germany, with *Microderoceras birchi* and *Promicroceras capricornoides* (Hoffmann, 1944 : 289), is presumably the exact equivalent of the Birchi Subzone in Britain. On the north side of the Massif Central ammonites are too scarce at this level for detailed subdivision (Mouterde, 1953 : 404). In the Stowell Park Borehole, Spath (1956 : 144) placed a subzone of "*birchi-turneri*" below one of "*capricornoides*", but *M. birchi* persists into the upper subzone (p. 152). Further evidence is needed before this sequence can be regarded as generally valid.

In southern Germany Walliser (1956 : 216–217) records *M. birchi* already in the Scipionianum Subzone. As some of the other species dealt with in his paper are interpreted widely, it is uncertain whether or not this record refers to *M. birchi* as strictly interpreted. It is clear, however, from this and other evidence, that *Microderoceras* may be found as low as the Semicostatum Zone, and that care is necessary in the use of the Birchi Subzone. It may be that the general non-recognition of the Brooki Subzone is due to earlier appearance of *M. birchi* in some regions.

## OBTUSUM ZONE

(Pl. 67, fig. 1)

INDEX SPECIES. *Asteroceras obtusum* (J. Sowerby, 1817 : 151, pl. 167 upper figure (lectotype, selected by Spath, 1925 : 300)).

NOMENCLATURE. The zone was introduced by Oppel (1856 : 50).

It includes the *obtusum*, *sagittarium*, *planicosta*, *stellare* and *denotatus* hemerae of Buckman (1930 : 45).

STRATIGRAPHY. In addition to *Asteroceras* the zone is characterized by the Asteroceratinae *Aegasteroceras* and *Epophioceras*, both of sporadic occurrence, and in the upper part by *Eparietites*. The accompanying Eoderoceratidae are *Promicroceras* and *Xipheroceras* but their species seem to be of less value for stratigraphical subdivision than the Asteroceratinae. The last species of *Arnioceras* are found in

the zone. The division into the Obtusum, Stellare and Denotatus Subzones, long accepted in England, reflects an evolutionary trend in the Asteroceratinae towards increasing compression of the whorls and reduction of the size of the umbilicus. The subzones have not been widely recognized on the Continent.

### *Obtusum Subzone*

(Pl. 67, fig. 1)

INDEX SPECIES. See Obtusum Zone.

NOMENCLATURE. In 1926 Lang used an " Obtusum Zone " in a very restricted sense, for a small part only of the Obtusum Zone of Oppel (see above). In 1942 Spath returned to the original use (approximately) of the Obtusum Zone, and he included a subzone of " *Promicroceras planicosta* or *obtusum* s.s." In 1956 (p. 150) he rejected *planicosta* in favour of *obtusum* as the subzonal index. The Planicosta Zone of Lang (1914 : 317, 319) is therefore a synonym. Dumortier's " Couches à *Ammonites planicosta* " (1867 : 95), however, are equivalent to the Raricostatum Zone.

STRATIGRAPHY. The subzone is well established in southern England, on the Dorset coast (Lang, 1926) and in the Stowell Park Borehole (Spath, 1956 : 150). To the north of the Massif Central (Mouterde, 1953 : 404) stratigraphical evidence is inadequate. In northern Germany *A. obtusum* and *A. stellare* have been recorded from the same bed (Hoffmann, 1950*a* : 82) but as the bed is 15–16 metres thick they may be in sequence ; *A. obtusum* alone is recorded from a lower horizon.

*Promicroceras planicosta* (J. Sowerby) and *Xipheroceras dudressieri* (d'Orbigny) occur in the subzone but both range up into the succeeding Stellare Subzone (Spath, 1956 : 150).

### *Stellare Subzone*

(Pl. 67, fig. 2)

INDEX SPECIES. *Asteroceras stellare* (J. Sowerby, 1815 : 211, pl. 93). The lectotype, designated by Donovan (1954 : 32), was refigured by Wright (1880, pl. 22, figs. 3–5).

NOMENCLATURE. Dumortier (1867 : 95) recognized " Couches à *Ammonites stellaris* " as a subdivision of his Oxynotus Zone (see p. 456) ; they were probably equivalent to Oppel's Obtusum Zone. In a restricted sense, a Stellare Zone was placed between Obtusum and Oxynotum by Buckman (1910*a* : xvi), and a Stellare Subzone of the Obtusum Zone was accepted by Lang (1914 : 320). The Landrioti Zone (Lang, 1926 : 159) is a synonym.

STRATIGRAPHY. A zone or subzone characterized by *Asteroceras stellare* has long been recognized by English authors as marking a distinct horizon above that of *A. obtusum*, but continental stratigraphers have not generally accepted it, although the index species is widely distributed in France and Germany according to records in the literature.

### *Denotatus Subzone*

(Pl. 66, fig. 4)

INDEX SPECIES. *Eparietites denotatus* (Simpson, 1855 : 76). The holotype was figured by Buckman (1912, pls. 67A, B).

NOMENCLATURE. The term was first used by Buckman (1919 : 120*b*) as " *stellare* (*denotatus*) zone " in the explanation of a plate. Earlier Buckman (1918 : 271) had placed the hemera of *denotatus* above that of *stellare*. Spath recognized a separate " *denotatus* zone " in 1925 (p. 264) and in 1942 placed the Denotatus Subzone at the top of the Obtusum Zone. The Lacunatum Zone of Söll (1956 : 375) is a synonym (see below).

STRATIGRAPHY. In Britain the subzone is well developed in Yorkshire, where, however, the presence of the other subzones of the Obtusum Zone is said to be doubtful (Spath, 1925 : 264). *Eparietites* occurs in the Vale of Gloucester and the subzone is probably present in the Stowell Park Borehole (Spath, 1956 : 150) and in Somerset, but on the south coast it is represented by a non-sequence (Lang, 1926 : 158).

In Württemberg the subzone has recently been recorded under the name of Lacunatum Zone, from which *Eparietites impendens* (Young & Bird) is noted (Söll, 1956 : 375, 382). According to Frebold (1925 : 15, 16) the corresponding strata are absent from north-western Germany. There is no evidence for the presence of the subzone in France.

The genus *Eparietites* is probably confined to the subzone, and *Aegasteroceras* persists into it from earlier beds.

## OXYNOTUM ZONE

(Pl. 66, fig. 5 ; Pl. 67, fig. 3)

INDEX SPECIES. *Oxynoticeras oxynotum* (Quenstedt, 1843 : 161 ; figured 1845, pl. 5, figs. 11*a*, *b*).

NOMENCLATURE. The zone was introduced by Oppel (1856 : 54). Dumortier (1867 : 93–97) extended the zone to include the Turneri to Raricostatum Zones (of the present paper) inclusive " Pour ne pas trop multiplier les subdivisions ", but recognized four subdivisions within it. The Bifer Zone of Emerson (1870 : 278, 280, 290) included rather more than Oppel's Oxynotum Zone and is rejected. Buckman's *polyophyllum*, *oxynotum*, *biferum*, *simpsoni*, *Gagaticeras*, *lacunata*, and *subpolita* hemerae (1930 : 45) are included in the zone.

STRATIGRAPHY. The subdivision here adopted is into two subzones, Spath's Lymense Subzone at the top being rejected for general use. *Oxynoticeras lymense* (Wright) is found only in Dorset, and the correlation of the beds in which it occurs is uncertain (Spath, 1956 : 149). The Lymense beds of Dorset are transferred to the Densinodulum Subzone of the Raricostatum Zone (see p. 459).

The Schlotheimiid genus *Angulaticeras* is present throughout the zone, but is of sporadic occurrence.

### *Simpsoni Subzone*

(Pl. 67, fig. 4)

INDEX SPECIES. *Oxynoticeras simpsoni* (Simpson, 1843 : 37–38). The holotype was figured by Buckman (1912, pls. 66A, B).

NOMENCLATURE. First used as a subzonal index by Spath (1942) : a *simpsoni* hemera had been introduced by Buckman (1918 : 269), and a *simpsoni* zone (?)[1] placed between *lacunatum* and *bifer* by Spath (1925 : 264). The Gagateum Zone of Hoffmann (1944 : 289) and the Praecursor Zone of Söll (1956 : 376) are synonyms.

STRATIGRAPHY. The subzone is present in Yorkshire and Lincolnshire, but on the Dorset coast, and probably elsewhere in the south of England, it is missing owing to a non-sequence. It has been recognized in North Germany (Hoffmann, 1944 : 289, as Gagateum Zone). In Württemberg, Söll has recently set up a Praecursor Zone which occupies the stratigraphical position of the Simpsoni Subzone and is here correlated with it. The index species, *Oxynoticeras praecursor* Söll, known only from septate inner whorls, appears not very different from *O. simpsoni*. The presence of the Simpsoni Subzone in the Côte d'Or may be indicated by the record of *Gagaticeras gagateum* (Young & Bird) by Mouterde (1953 : 278, 280, 287).

In addition to the index species, *Gagaticeras gagateum* occurs in the subzone, but may also range higher. *Cheltonia* is present and it also occurs in the Oxynotum Subzone. *Slatterites* belongs to this subzone, to judge from its association with *O.* aff. *simpsoni* noted by Spath (1925 : 110, expl. of fig. (*c*)), and from French records (Mouterde, 1953).

### *Oxynotum Subzone*

(Pl. 66, fig. 5 ; Pl. 67, fig. 3)

INDEX SPECIES. As for Oxynotum Zone.

NOMENCLATURE. The index species was used in a restricted stratigraphical sense by Buckman (1918 : 269) who introduced an *oxynotum* hemera.

Spath (1942) adopted the term Bifer Subzone for this subdivision, with Oxynotum (*s.s.*) as an alternative.

It is doubtful whether Spath intended to restrict the broad Bifer Zone of Emerson (1870 : 278, etc.) ; more probably he derived his subzone from the *biferum* hemera of Buckman (1918 : 269). *Oxynoticeras oxynotum* is now used as the subzonal index on account of uncertainty as to the vertical range of *Bifericeras bifer* (Quenstedt) (see below).

STRATIGRAPHY. The subzone corresponds to the range of the index species. *Cheltonia* occurs throughout the subzone but is not restricted to it. In Württemberg, *Bifericeras bifer* is restricted to the lower part of the subzone and Söll (1956 : 371, 377) has therefore recognized a Bifer Subzone at the base of his Oxynotum Zone (= Oxynotum Subzone of this paper). In some British sections *B. bifer* and related species are commonest in the upper part of the subzone, and Söll's arrangement

[1] The status of the subdivisions in Spath's 1925 Table is not clear. Some of them are referred to in the text as zones.

is not, therefore, of general application. Species of *Bifericeras* allied to, if not identical with *B. bifer* occur also in the succeeding Densinodulum Subzone. *Angulaticeras* may be found at any level in the subzone, and *Palaeoechioceras*[1] occurs in southern England.

The subzone is present in England, but is absent from the Dorset coast. It is generally absent from North-west Germany (Hoffmann, 1949 : 114), but the fauna is well known from Swabia. Mouterde (1953 : 119, 349) records the subzone from the Côte d'Or and the northern side of the Massif Central, in condensed facies.

## RARICOSTATUM ZONE

(Pl. 68, fig. 1)

INDEX SPECIES. *Echioceras raricostatum* Zieten (1831 : 18, pl. 13, figs. 4*a–c*). The type figure is poor but the species is believed to be represented by Quenstedt (1845, pl. 4, figs. 3*a–d*). See Donovan (1958*a* : 18).

NOMENCLATURE. The zone was introduced by Oppel (1856 : 56). It includes the following of Buckman's hemerae (1930 : 43–45) : *Radstockiceras*, *rothpletzi* [1st *Echioceras*], *glevense*, armatoid, *lymense*, *densinodulum* [*densinodum*], *subplanicosta*, *bispinigerum*, *anguiforme*, *miles*, *simile*, *costidomus*, *rhodanicum*, *tubellus*, *boreale*, *raricostatoides*, *Plesechioceras*, *planum*, *macdonnellii*, *aplanatum* [*Metechioceras*], *Euechioceras* and *defluxum* : possibly a record number for a single zone. There is very little significance in the order in which these hemerae were placed by Buckman : many of them represent hypothetical horizons and cannot be placed in their respective subzones.

STRATIGRAPHY. The zone as now interpreted is larger than the Raricostatum Zone of Spath (1942) by the inclusion at the base of the beds attributed to his Lymense Zone (see above, p. 456). The upper three subzones are those accepted by Spath, but the lowest is replaced by the Densinodulum Subzone, as explained below.

The zone corresponds to the range of the genus *Paltechioceras*. In some areas this genus is found only above the Raricostatum Subzone, but evidence from Raasay and from unpublished sections in southern England shows that it occurs also in the Densinodulum Subzone. The Eoderoceratidae *Bifericeras*, *Crucilobiceras* and "*Hemimicroceras*"[2] occur in the earlier part of the zone, and *Eoderoceras* probably persists throughout.

Spath (1956 : 148) thought that a Tubellus Subzone might eventually be established at the top of the Raricostatum Zone or at the base of the Jamesoni Zone. Recent evidence shows that "*Tubellites*" *tubellus* (Simpson), probably a species of *Gemmellaroceras*, is either long ranging, or likely to be confused with similar small, smooth species or smooth inner whorls of larger species, at widely different horizons. It has therefore no stratigraphical value.

[1] *Hypechioceras* Spath (1956 : 149) is a synonym.

[2] i.e. the species described under this name by Trueman & Williams (1927), which require a new generic name since *Hemimicroceras*, as properly defined, appears to be synonymous with *Bifericeras*.

### *Densinodulum Subzone*

(Pl. 67, fig. 5)

INDEX SPECIES. *Crucilobiceras densinodulum* Buckman (1923*a*, pl. 442).

NOMENCLATURE. The Densinodulum Zone was introduced by Lang (1926 : 157) in a more restricted sense than now used ; the index species had already been used for a hemera by Buckman (1923*a*, pl. 442). Several other zones introduced by Lang (1926) have equal priority : their indices are *Eoderoceras bispinigerum* (Buckman), *E. obesum* (Spath), and *Crucilobiceras ornatilobatum* (Spath). Bispinigerum Subzone was preferred by Spath (1942) ; for discussion see below. The Lymense Zone (Spath, 1925 : 263 ; Lang, 1926 : 157) and Subplanicosta Zone (Hoffmann, 1948 : 154) are also synonyms.

The name Armatum Subzone, if considered to have priority, should be applied to this subzone, but was rejected by Spath (1942) and the present authors are in agreement. It dates from Oppel (1856 : 117, etc.) who used it for basal beds of the continental Middle Lias (i.e. the Pliensbachian Stage) but pointed out that this usage was conditional on his having correctly identified Sowerby's *Ammonites armatus* in Swabia. His identification has proved to be incorrect (the ammonites in question are *Apoderoceras*). Oppel's Armatum Zone was therefore misnamed and the true *Ammonites armatus* is not accepted as having priority as a zonal index from 1856.

STRATIGRAPHY. The subzone replaces the Lymense and Bispinigerum Subzones of Spath (1942) for, except locally, it is not possible to distinguish more than one subzone between the Oxynotum and Raricostatum Subzones. The index species ranges through the " Lymense " and " Bispinigerum " Subzones in Dorset, and is a common ammonite in a number of areas. It is therefore preferred to the index species of equal priority, mentioned above, which range through only part of the subzone, and which are less abundant as fossils.

The base of the subzone in most sections is defined by the first appearance of *Crucilobiceras*. Rarely, a *Paltechioceras* fauna is found at this level, and where present may be taken to mark the base of the subzone and of the Raricostatum Zone (see above). The top of the subzone is marked by the incoming of *Echioceras*. *Crucilobiceras densinodulum* ranges above this level, for example on the Dorset coast, but it does not appear possible to find a more suitable index species. " *Hemimicroceras* " is characteristic of the subzone in some places (for instances the Stowell Park Borehole, Spath, 1956 : 148–149) although it has not been found on the Dorset coast, but " *H.*" *subplanicosta* (Oppel) ranges up into the Raricostatum Subzone at Stowell Park and in North-west Germany (Hoffmann, 1950 : 110). This species was used as a zonal index for the present subzone by Hoffmann (1948 : 154, see also 1944 : 289) but is no more suitable than *C. densinodulum* which has priority.

Species of *Eoderoceras*, including *E. bispinigerum* (Buckman) and *E. armatum* (J. Sowerby), occur in the subzone in Dorset, but species close to the last are found at higher horizons. *Gleviceras* similarly occurs throughout the subzone and also ranges higher ; the succession of species is not known.

### *Raricostatum Subzone*

(Pl. 68, fig. 1)

INDEX SPECIES. .See Raricostatum Zone.

NOMENCLATURE. See Raricostatum Zone. *Echioceras raricostatoides* Vadasz was used as the index of a hemera by Buckman (1918, Table facing p. 267) and of a zone by Lang (1926 : 155). Spath (1942) adopted it in preference to Raricostatum (*s.s.*), but in the present writer's view (Donovan, 1958*a* : 19) the available evidence does not allow a decision as to whether *E. raricostatoides* is a separate species from *E. raricostatum*. Exhaeredatum Zone of Lang (1926 : 155) is a synonym, as explained below. Aeneum Zone of Lang (1926 : 155) is also a synonym (Spath, 1956 : 148).

STRATIGRAPHY. The base of the subzone is marked by the first appearance of *Echioceras*, and the top by its replacement by *Paltechioceras*. *Echioceras raricostatum* is usually common, whilst *E. aeneum* Trueman & Williams occurs in the lower part of the subzone and may locally appear below *E. raricostatum*, as on the Dorset coast (Lang, 1926 : 155). The genera *Bifericeras* and *Crucilobiceras* occur in the subzone, and *Bifericeras* probably does not range higher ; it is represented by the smooth *B. parvum* (Buckman). A bed in Dorset with the rare genus *Epideroceras* was separated as Exhaeredatum Subzone (see above), but later collecting showed it to belong to the Raricostatum Subzone (Spath, 1956 : 148).

The subzone has been widely recognized throughout the province by the presence of the index species.

### *Macdonnelli Subzone*

(Pl. 67, fig. 6)

INDEX SPECIES. *Leptechioceras macdonnelli* (Portlock, 1843 : 134, pl. 29A, fig. 12). The holotype was refigured by Wright (1880, pl. 37, figs. 3, 4).

NOMENCLATURE. First used as the "Zone of *Leptechioceras macdonnelli*" by Lang (1926 : 155), deriving probably from a hemera of the same name (Buckman, 1918, Table V). Spath (1942) reduced it to a subzone of the Raricostatum Zone.

STRATIGRAPHY. The subzone is defined by the range of the genus *Leptechioceras*, which in Britain lies above that of *Echioceras*. In thick facies there is a gap between the ranges of the two genera, while in thinner developments they may be associated, possibly due to condensation of the sequence. *Paltechioceras* exists throughout the subzone (see remarks above on its range, p. 458). Eoderoceratidae occur but are generally less common than Echioceratidae.

The subzone is present in Raasay (Hebrides), Yorkshire and the Stowell Park Borehole, and typical species are recorded from condensed sequence in the Radstock area of Somerset (Tutcher & Trueman, 1925 : 645). On the Dorset coast it falls in the non-sequence between beds 104 and 105 (Lang, 1928 : 195). On the Continent, it has not been identified in actual sections, but *Leptechioceras* occurs in the Côte d'Or as *L. nodotianum* (d'Orbigny).

In North Germany Echioceratidae appear to be rare in the later Raricostatum

Zone and Hoffmann has used zones based on Eoderoceratidae. In 1944 (pp. 289–290) the zone of *Eoderoceras postarmatum* Hoffmann was placed above the Raricostatoides Zone (i.e. Raricostatum Subzone of the present paper), but in 1948 (p. 159) it was replaced by the zone of *E. miles* (Simpson), on the grounds that this species is more common in North-west Germany than *E. postarmatum* (Hoffmann, 1950 : 78). The Miles Subzone will presumably continue to be used in North-west Germany, to replace Macdonnelli and Aplanatum Subzones of the present scheme, but where Echioceratidae are present they are superior for stratigraphical purposes, because species of *Eoderoceras* are not very easy to identify and are comparatively long ranging.

According to Hoffmann (1950 : 77), the Miles Subzone is absent from South-west Germany.

### *Aplanatum Subzone*

(Pl. 68, fig. 2)

INDEX SPECIES. *Paltechioceras aplanatum* (Hyatt, 1889 : 146, figs. 21, 24). A photograph of the holotype was published by Buckman (1926, pl. 640).

NOMENCLATURE. First used, as a zone, by Lang (1926 : 155) ; introduced as a hemera by Buckman (1918, Table V). In 1942 Spath placed it as the uppermost subzone of the Raricostatum Zone of Oppel.

STRATIGRAPHY. The index species is believed to be restricted to the subzone, but other species of *Paltechioceras* occur at horizons from the base of the Raricostatum Zone upwards (see above, p. 458). Where the Macdonnelli Subzone can be recognized, the Aplanatum Subzone may be conveniently defined as the part of the Raricostatum Zone lying above it.

The known distribution of the subzone is similar to that outlined for the Macdonnelli Subzone ; though well established in Britain, there is little evidence from the Continent. In North-west Germany the beds attributed to the subzone in Britain are presumably represented by part of the Miles Subzone which is discussed above. In France, on the northern border of the Massif Central, Mouterde (1953 : 404) notes "*Plesechioceras nodotianum*" (*recte Leptechioceras*) and "*Euechioceras*" (*recte Paltechioceras*) as occurring above *Echioceras raricostatum*.

## PLIENSBACHIAN STAGE

The term Charmouthian, usually attributed to Mayer-Eymar (1864) but probably first published by Renevier (1874 : 242, pl. 6) is synonymous with Oppel's Pliensbachian and with d'Orbigny's long-rejected Liasien. Renevier himself did not favour the term, but it has been used by various authors. Rollier (1915) proposed to restrict the meaning of Charmouthian to Margaritatus and Spinatum Zones, but he had already been forestalled in the usage : Buckman (1910*a* : xvi) had unjustifiably used the term in a different way, namely for the zones from Raricostatum to Davoei inclusive. Lang (1912) maintained that, if used at all, Charmouthian should be understood in its original sense.

## LOWER PLIENSBACHIAN OR CARIXIAN SUBSTAGE

The natural division of the stage into two parts at the appearance of the Amaltheidae was recognized by Oppel (1856 : 116). Carixian was proposed by Lang (1913) as an alternative to Lower Pliensbachian. Buckman subdivided the Carixian of the present paper (part of his Charmouthian ; see above) into Wessexian and Hwiccian Stages[1] (1917 ; 1918 : 263, 266), the division between the two falling within the Ibex Zone. These names were introduced to fit Buckman's hemeral system and are now considered superfluous, especially because they cut across the long-accepted zonal boundaries.

As originally defined Buckman's Deroceratan Age corresponded to the Pliensbachian Stage plus the Raricostatum Zone. It was later much restricted, and in Buckman's final scheme Deroceratan (*pars*), Polymorphitan and Liparoceratan Ages fall in the Lower Pliensbachian.

Oppel's zones are used here. The Jamesoni Zone is slightly restricted, by the transference of Masseanum Subzone from the top of the Jamesoni Zone to the base of the Ibex Zone, resulting in a more balanced arrangement. Four subzones are now recognized in the Jamesoni Zone as thus restricted. The Davoei Zone remains as used by Spath (1942) with the substitution of Capricornus for Lataecosta as the middle subzone.

### JAMESONI ZONE

(Pl. 68, fig. 3)

INDEX SPECIES. *Uptonia jamesoni* (J. de C. Sowerby, 1827 : 105, pl. 555, fig. 1).

NOMENCLATURE. The zone was introduced by Oppel (1856 : 118).

STRATIGRAPHY. The extent of the zone in terms of modern detailed stratigraphy is adequately indicated by Oppel's list of characteristic ammonites, bearing in mind that his *Ammonites armatus* was misidentified (see p. 459). According to his definition it includes beds from the Taylori Subzone to the Masseanum Subzone inclusive. The Masseanum Subzone is here excluded, for reasons discussed below (see Ibex Zone).

#### *Taylori Subzone*

(Pl. 68, fig. 5)

INDEX SPECIES. *Phricodoceras taylori* (J. de C. Sowerby, 1826 : 23, pl. 514, fig. 1).

NOMENCLATURE. The subzone or horizon of *P. taylori* was introduced by Spath (1923*a* : 9). Synonyms are : Leckenbyi Zone (Lang, 1928 : 195) ; Nodogigas-Taylori Zone (Hoffmann, 1948 : 159) ; Peregrinum Subzone (Spath, 1923*a* : 9). The Armatum Zone as incorrectly used by Oppel and many other authors (see p. 459) is a synonym.

Buckman's hemerae (1930 : 43, 44) of *armatum*, *leckenbyi*, *Phricodoceras*, *peregrinus* and *phyllinus* probably all fall within the subzone.

[1] Called ages by Buckman, but properly stages since they were founded on geographical names. Ages were based on fossil names, but Buckman sometimes confused the two terms ; see Arkell (1933 : 23–25).

STRATIGRAPHY. The subzone includes the beds separated as the Peregrinum Zone in Dorset, and *P. taylori* is used as the index, following Spath (1942), in preference to *Gemmellaroceras peregrinum* (Haug) which has equal priority, because it is more distinctive. The subzone is also characterized by the genus *Apoderoceras*, and is recognized throughout the province.

### *Polymorphus Subzone*

(Pl. 68, fig. 4)

INDEX SPECIES. *Polymorphites polymorphus* (Quenstedt, 1845 : 86, pl. 4, figs. 9–13).

NOMENCLATURE. Introduced by Spath (1923*a* : 9). The "*caprarius* (= lower *polymorphus*)" zone of Dorset, mentioned by Spath (1926 : 47, note 1) is a synonym. Includes the *caprarius*, *polymorphus* and *trivialis* hemerae of Buckman (1918 : 266 ; 1925 : 77 ; 1930 : 43).

STRATIGRAPHY. The subzone was abandoned by Spath (1942), but there is an interval, in the British successions, between the Taylori and Brevispina Subzones for which it is convenient to have a name. Sufficiently detailed stratigraphy from continental localities is not available. In North-west Germany this part of the sequence seems to be absent or condensed, to judge from borehole sections (Hoffmann, 1950 : 100–119), and the sections on the north side of the Massif Central (Mouterde, 1953) have the same disadvantage. *Radstockiceras* (= *Metoxynoticeras*) occurs in the subzone, and *Platypleuroceras caprarium* (Quenstedt) characterizes the upper part.

### *Brevispina Subzone*

(Pl. 69, fig. 1)

INDEX SPECIES. *Platypleuroceras brevispina* (J. de C. Sowerby, 1827 : 106, pl. 556, fig. 1). Sowerby's figured specimen was refigured by Wright (1880, pl. 32, figs. 2, 3).

NOMENCLATURE. The Brevispina Zone dates from von Seebach (1864 : 21) who used it in a very wide sense. A subzone of *P. brevispina* was used by Spath (1922*a* : 550 ; 1923*a* : 9). The subzone includes the *brevispina* and *Platypleuroceras* hemerae (Buckman, 1918 : 266 ; 1930 : 43).

STRATIGRAPHY. The subzone has been widely recognized by the presence of the index species, although Hoffmann (1950 : 77) does not separate it from his Jamesoni Zone. It includes the last species of *Polymorphites*, such as *P. trivialis* (Simpson) and *P.* cf. *quadratus* (Quenstedt).

### *Jamesoni Subzone*

(Pl. 68, fig. 3)

INDEX SPECIES. As for the zone.

NOMENCLATURE. None of the alternatives to the use of *Uptonia jamesoni* as a

subzonal as well as a zonal index is entirely satisfactory. They are : Obsoleta Zone (Lang, 1928 : 193), Bronni Subzone (Spath, 1942 : 265) and Pettos Zone (Thompson, 1899 : 75). The *bronni*, *obsoleta*, *jamesoni* and *pettos* hemerae fall within the subzone (Buckman, 1918 : 266 ; 1930 : 42–43).

Stratigraphy. The subzone is defined by the range of the index species. Spath (1922*a* : 550 ; 1923*a* : 9) and Lang (1928 : 192–193) placed the horizon of *Uptonia obsoleta* (Simpson) below that of *U. jamesoni*. *U. obsoleta* may in some areas be found in association with *Platypleuroceras brevispina*. *Uptonia bronni* (Römer) is restricted to the upper part of the subzone. The Pettos Zone was set up for a horizon below that of *U. jamesoni* in Warwickshire, England, but on the Dorset coast *Coeloceras pettos* (Quenstedt) occurs at the top of the subzone. *C. pettos* is too rare to be suitable as an index fossil.

The subzone is recognized in Britain and on the north side of the Massif Central (Mouterde, 1953 : 153, 200).

## IBEX ZONE

(Pl. 69, fig. 4)

Index species. *Tragophylloceras ibex* (Quenstedt, 1843 : 179, and 1845, pl. 6, fig. 6).

Nomenclature. The zone was first used by Oppel (1856 : 122).

Stratigraphy. *Tragophylloceras ibex* occurs in the lower part of the zone in Dorset, being replaced in the Luridum Subzone by *T. loscombi* (J. Sowerby), which ranges up into the Davoei Zone. The zone is now used in a wider sense than that of Oppel, by the inclusion of the Masseanum Subzone at the base. Oppel recorded *Ammonites masseanus* d'Orbigny as a fossil of the Jamesoni Zone and cited it from the same horizon as *Ammonites jamesoni* (1856 : 123), but in areas where detailed collecting has been carried out neither *Uptonia jamesoni* nor any other species of *Uptonia* persists into the beds with *Tropidoceras masseanum*, so it is more convenient to terminate the Jamesoni Zone with the extinction of *Uptonia*, and take the Masseanum Subzone (as did Mouterde, 1953 : 408) as the base of the Ibex Zone.

### *Masseanum Subzone*

(Pl. 69, fig. 2)

Index species. *Tropidoceras masseanum* (d'Orbigny, 1844 : 225, pl. 58). The holotype was refigured by Nicklès (1903, pl. 8).

Nomenclature. Introduced by Spath (1923*a* : 9) as the uppermost subdivision of Oppel's Jamesoni Zone. Includes the *masseanus* and *ellipticum* hemerae of Buckman (1918 : 266 ; 1930 : 42).

Stratigraphy. The base of the subzone is marked by the appearance of the genus *Tropidoceras*, the index species being accompanied by allied species including *T. ellipticum* (J. Sowerby) and *T. galatense* (Gemmellaro). The subzone is recognizable throughout Britain, and on the north side of the Massif Central (Mouterde, 1953 : 297, 408). *Tropidoceras* cf. *masseanum* is recorded from North Bavaria (Krumbeck,

1936 : 194, 199, etc.), from condensed facies in which the stratigraphical order of the ammonites has not been determined.

### *Valdani Subzone*

(Pl. 69, fig. 5)

INDEX SPECIES. *Acanthopleuroceras valdani* (d'Orbigny, 1844 : 255, pl. 71).

NOMENCLATURE. Introduced as the Zone of *Ammonites Valdani* by Collenot (1869 : 166), it was in 1942 reduced to the status of a subzone of the Ibex Zone by Spath. The Actaeon, Maugenesti and Centaurus Subzones (Spath, 1923*a* : 9) are synonyms (see below). The last-named was perhaps derived from Buckman's *centaurus* hemera, or from the Centaurus Zone which Emerson (1870 : 278, 280, 302) established as a subdivision of von Seebach's Brevispina Zone. The Venarensis Zone (Collenot, 1869 : 166), which Collenot placed above his Valdani Zone, has equal priority and is a synonym. It is unsuitable because *Ammonites venarensis* Oppel is not well known and appears to be rare.

The subzone includes the *ibex, maugenesti, valdani, actaeon, cheltiense, carinatum* and *centaurus* hemerae of Buckman (1918 : 264 ; 1925 : 77 ; 1930 : 42).

STRATIGRAPHY. Spath (1923*a*) divided the beds now included in the subzone into the Maugenesti, Actaeon and Centaurus Subzones. It now appears that in some areas the order of the index species *Acanthopleuroceras maugenesti* (d'Orbigny) and *Tropidoceras actaeon* (d'Orbigny) is reversed, for example on the borders of the Massif Central (Mouterde, 1953 : 153), and Spath (1942) himself later adopted the prior Valdani Subzone to include both these horizons. He retained the Centaurus Subzone above Valdani, but recent evidence from England shows that the range of *Beaniceras*[1] *centaurus* (d'Orbigny) overlaps that of *Acanthopleuroceras valdani* and *A. maugenesti*. Association of the two genera is also recorded from the north side of the Massif Central (Mouterde, 1953 : 408) where it may, however, be due to condensation of the sequence.

The subzone is widely recognized throughout the province. *Acanthopleuroceras* is characteristic of the subzone, and in some areas appears to be accompanied by species of *Tropidoceras* such as *T. actaeon, T. calliplocoides* (Spath) and *T. stahli* (Oppel), although on the Dorset coast the latter fauna succeeds *A. valdani*. *Tropidoceras* in any case persists into the next subzone (see below). *Beaniceras centaurus*, in some areas at least, survives into higher beds than *Acanthopleuroceras valdani*, but these beds are included in the Valdani Subzone, of which the upper limit is taken at the first appearance of *Beaniceras luridum*.

### *Luridum Subzone*

(Pl. 69, fig. 6)

INDEX SPECIES. *Beaniceras luridum* (Simpson, 1855 : 46). The type of the species was figured by Buckman (1913, pl. 73).

[1] The author of this section prefers to regard *Beaniceras*, *Androgynoceras* s.s. and *Oistoceras* as subgenera, marking successive stages in the evolution of the genus *Androgynoceras* (Donovan, 1954 : 16). They are here written as genera for the sake of brevity.

NOMENCLATURE. The subzone is here proposed for the first time.

STRATIGRAPHY. The new subzone is proposed for the uppermost part of the Ibex Zone, in which *B. centaurus* is replaced by *B. luridum* and allied " species " such as *B. geyeri* (Spath) and *B. subluridum* Spath. The index species accompanied by *Liparoceras* species such as *L. elegans* Spath, *L. pseudostriatum* Trueman and *Tragophylloceras loscombi* (J. Sowerby), is present in Dorset in the Belemnite Stone (Lang, 1928 : 189, bed 121), but this part of the Dorset coast sequence is condensed and incomplete. The subzone is distinct in the thicker clay facies in Gloucestershire, and is well shown in the brick pit near Blockley station, mentioned by Richardson (1929 : 15). The ammonite succession here has been worked out by Dr. J. H. Callomon, who is preparing an account for publication. The type of *B. luridum* comes from the Yorkshire coast, but its exact horizon is apparently unknown. On the northern side of the Massif Central, the index species is recorded by Mouterde (1953 : 408) as characteristic of a horizon at the top of the Ibex Zone, accompanied by *Liparoceras kilsbiense*, above the beds with *Acanthopleuroceras* and *B. centaurus*.[1] The subzone has not been definitely identified in Germany.

## DAVOEI ZONE

(Pl. 70, fig. 1)

INDEX SPECIES. *Prodactylioceras davoei* (J. Sowerby, 1822 : 71, pl. 350).

NOMENCLATURE. The zone was introduced by Oppel (1856 : 126). The Capricornus Zone, when set up, was a synonym, but is now retained as a subzone. The Fimbriatus Zone of von Schloenbach (1863) presumably includes the Davoei Zone.

Buckman's Liparoceratan Age corresponds to the Davoei Zone, which includes the hemerae of " *henleyi* ", *lataecosta*, *davoei*, *daedalicosta* and *Oistoceras* [*striatum*], but little significance can be attached to the order in which they were listed by Buckman (1918 : 264 ; 1930 : 42).

STRATIGRAPHY. The zone was subdivided by Lang (1914, Table facing p. 308 ; 1936 : 431–435), but the Bechei Subzone introduced in 1936 has since been abandoned (see Capricornus Subzone, below) and a three-fold subdivision, founded on species of the family Liparoceratidae, remains. *Prodactylioceras davoei* occurs in the Capricornum and Figulinum Subzones. In addition to Liparoceratidae and *Lytoceras*, *Tragophylloceras loscombi* occurs throughout the zone.

### *Maculatum Subzone*

(Pl. 70, fig. 4)

INDEX SPECIES. *Androgynoceras maculatum* (Young & Bird, 1822 : 248, 327, pl. 14, fig. 12). The holotype was figured by Buckman (1912, pl. 45A, B). For full description and illustration see Spath (1938 : 126).

[1] Mouterde states that *B. centaurus* occurs in England at the level at which he finds *B. luridum* ; this is evidently a misconception.

NOMENCLATURE. The term was first used, as a zone, by Lang (1936 : 434). Spath (1938 : 34 ; 1942) employed it as the lowest subzone of Oppel's Davoei Zone. The Striatum Zone of Buckman (1910*a* : xvi), which originated as the hemera of *Liparoceras striatum* (Buckman, 1898, Table facing p. 450), is a synonym, but is considered invalid as the index species when proposed (as *Nautilus striatus* Reinecke, 1818) was a homonym of *Nautilus striatus* J. Sowerby, 1817. It is, in any case, uncertain whether Buckman correctly identified Reinecke's *striatus* and correctly placed it stratigraphically.

STRATIGRAPHY. The subzone corresponds to the range of *Androgynoceras maculatum*, and is recorded on the Dorset coast (Lang, 1936), in the Stowell Park Borehole (Spath, 1956 : 145) and in Yorkshire (Spath, 1938 : 26–27). It has not been separated from the Capricornus Subzone in Germany, although the index species has been recorded from Württemberg (Spath, 1938 : 132–133). In France, on the borders of the Massif Central, the index species is recorded from the same bed as *A. lataecosta* (J. de C. Sowerby), a species of the Capricornus Subzone (Mouterde, 1953 : 152, 322) ; this may well be due to condensation of the sequence. In spite of the present lack of confirmation from the Continent, the subzone is retained as its consistent position in England suggests that it marks an evolutionary stage in the *Androgynoceras* lineage, and may be of use over a wide area.

### *Capricornus Subzone*

(Pl. 69, fig. 3)

INDEX SPECIES. *Androgynoceras capricornus* (Schlotheim, 1820 : 71). Lectotype figured by Spath (1938 : 150, pl. 23, fig. 1).

NOMENCLATURE. The Capricornus Zone was first used by Wright (1863 : 79) who stated that the Davoei Zone of Oppel (which has priority) was a synonym. No reason for the substitution was given. The term is retained in a more restricted sense as a subdivision of the Davoei Zone. The Bechei Zone (Lang, 1936 : 432) is now included in the Capricornus Subzone, its general applicability being unconfirmed (Spath, 1956 : 145). The following are also junior synonyms : Daedalicosta Zone (Trueman, 1919 : 252), of which the index species is said to be a synonym of *Liparoceras* (*Becheiceras*) *bechei* (J. Sowerby) (Spath, 1938 : 75) ; Henleyi Zone (Collenot, 1869 : 166) ; Lataecosta Subzone (Lang, 1914, Table facing p. 308) as restricted by Lang (1936 : 433) ; *Liparoceras* Subzone (Lang, 1914, Table facing p. 308), superseded by Bechei Zone.

STRATIGRAPHY. The subzone embraces the ranges of *Androgynoceras capricornus* and *A. lataecosta* (J. de C. Sowerby), the latter immediately succeeding *A. maculatum* in Britain. The subzone is widely recognized, although, as remarked in the notes on Maculatum Subzone, it has not been separated from that subzone in Germany or in France. The highest part of the subzone was at one time separated as the Bechei Subzone, which has since been rejected (Spath, 1942 ; 1956 : 145). *Liparoceras* (*Becheiceras*) *bechei* is an indifferent zonal fossil, being difficult to distinguish from later species of the subgenus which range well into the Margaritatus Zone. A horizon

of *L.* (*B.*) *bechei* is listed by Krumbeck (1936, Table 28) from northern Bavaria at a higher level (Figulinum Subzone or above), which confirms the unsuitability of the fossil as a subzonal index.

### *Figulinum Subzone*

(Pl. 70, fig. 5)

INDEX SPECIES. *Oistoceras figulinum* (Simpson, 1855 : 47, 48), the type of which was figured by Buckman (1911*a*, pl. 26A). See also Spath (1938 : 162).

NOMENCLATURE. The subzone was introduced by Lang (1936 : 431) as the highest subzone of the Davoei Zone. It superseded the same author's " Subzone of *Oistoceras* " (1914, Table facing p. 308). Hoffmann's zone of *Prodactylioceras davoei* and *Oistoceras curvicorne* is the equivalent of the Figulinum Subzone (Hoffmann, 1949 : 115). Davoei Zone (Oppel, 1856), as strictly interpreted, has priority over Figulinum Subzone, but it is more consistent to subdivide the Davoei Zone by means of species of Liparoceratidae rather than to use Davoei for both zone and subzone.

STRATIGRAPHY. The index species is widely distributed in England, France and Germany. The base of the subzone may be taken at the appearance of *Oistoceras*. *Androgynoceras* s.s. persists into the subzone in some areas, as in Gloucestershire and Lincolnshire (Spath, 1956 : 145), and the borders of the Massif Central (Mouterde, 1953 : 409), *A. capricornus* of the underlying subzone being replaced by *A. artigyrus* (Brown). *Prodactylioceras* appears at about the base of the subzone (just below *Oistoceras* in Dorset, England), and *Liparoceras* (*Becheiceras*) ranges throughout. The subzone is terminated above by the appearance of the *Amaltheus stokesi* fauna, marking the base of the Margaritatus Zone.

## UPPER PLIENSBACHIAN OR DOMERIAN SUBSTAGE

The term Domerian was proposed by Bonarelli (1894) for the Margaritatus and Spinatum Zones as defined by Oppel (1856). It is, therefore, an alternative to Upper Pliensbachian, even though the type area of the Domerian is Monte Domero (now known as Monte Domaro), Tuscany, Italy, which is outside the North-west European Province. By definition the Domerian corresponds to the range of the distinctive family Amaltheidae and to the British Middle Lias.

The limits of the Margaritatus and Spinatum Zones are the same as in Oppel's original definitions (1856 : 129ff., 138ff.).

### MARGARITATUS ZONE

(Pl. 70, fig. 3)

INDEX SPECIES. *Amaltheus margaritatus* de Montfort (1808 : 91). The neotype was figured by Howarth (1958 : 15, text-fig. 8).

NOMENCLATURE. Introduced by Oppel (1856 : 129). Synonyms are the Algovianum Zone of Buckman (1910*a* : xvi) and the Nitescens Zone of Thompson (1910 :

458) ; both were based on species of *Arieticeras* which occur widely in the Margaritatus Zone. The " Zone de l'*Ammonites zetes* d'Orbigny " (*Phylloceras*) of Collenot (1869 : 172) is also a synonym. The zone includes the *Seguenziceras* [*algovianum*] and *margaritatus* hemerae of Buckman (1930 : 41–42).

Stratigraphy. The base is clearly defined over most of the area by the sudden appearance of *Amaltheus stokesi*. The range of *Amaltheus* does not distinctly overlap with that of the highest *Oistoceras* at the top of the Davoei Zone, although both have been found in the same bed in Lincolnshire (Howarth, 1958 : xii) and at two localities in North-west Germany (Lange, 1932 : 239 ; Kumm, 1941 : 283). The top is drawn immediately below the lowest *Pleuroceras*. Spath's divisions (1942) of the zone were founded on Frentzen's monograph (1937) on the Amaltheidae of South-west Germany, but it has been found subsequently that the earliest Amaltheidae fauna is not common in this area and a further subzone of *Amaltheus stokesi* has had to be inserted at the base. All the subzones are recognizable in the Aveyron district of South-east France, but they have not yet been recognized in other areas of France, nor in North Germany.

In the southern part of the province, especially south-eastern France, Hildoceratidae, Dactylioceratidae and Amaltheidae are all common in the Margaritatus and Spinatum Zones. Southwards in the Mediterranean Province Amaltheidae become rare and the other families become abundant, whilst in the central and northern parts of the North-west European Province Dactylioceratidae are absent and Hildoceratidae are far less abundant than Amaltheidae. Zonal schemes founded on the Hildoceratidae in the Mediterranean and on the Amaltheidae in North-west Europe can be correlated against each other in areas such as Aveyron where the two provinces meet.

### *Stokesi Subzone*

(Pl. 70, fig. 2)

Index species. *Amaltheus stokesi* (J. Sowerby, 1818 : 205, pl. 191). The holotype was figured by Howarth (1958, pl. 1, fig. 7).

Nomenclature. First used by Lang (1936 : 431) for the beds at the base of the Margaritatus Zone near Seatown, Dorset. Includes the *fieldingi* and *clevelandicus* hemerae of Buckman (1930 : 42).

Stratigraphy. The subzone corresponds to the range of *Amaltheus stokesi*, for the upper boundary is marked by the appearance of *A. subnodosus* (Young & Bird) and at this level *A. stokesi* is replaced by *A. margaritatus*. There are few other Amaltheidae in this subzone : *Amaltheus bifurcus* Howarth, *A. wertheri* (Lange) and rare examples of *Amauroceras ferrugineum* (Simpson) occur in Britain and *Amaltheus evolutus* Buckman in South-east France. Species of the Hildoceratidae genera *Arieticeras* and *Leptaleoceras* are found in England mainly in this part of the Margaritatus Zone, and there are also representatives of the genera *Tragophylloceras*, *Liparoceras* (*Becheiceras*) and *Metacymbites*.

In most areas of England this subzone is much thicker than any of the other subzones of the Middle Lias and the characteristic ammonites are abundant, but

in other areas of the province it is either very thin, yet to be found, or absent. In the Hebrides it is poorly developed and the index ammonite is rare.

The only definite records from France and Germany are at Aveyron, where the " passage beds " and " subzone $a_1$" of Monestier (1915, 1928) have yielded specimens of *Amaltheus stokesi* and therefore belong to this subzone, and in Swabia where this species and *A. bifurcus* have recently been found. The beds at Aveyron also contain several species of *Protogrammoceras*, *Fuciniceras* and *Arieticeras*.

### *Subnodosus Subzone*

(Pl. 71, fig. 3)

INDEX SPECIES. *Amaltheus subnodosus* (Young & Bird, 1828 : 258, pl. 13, fig. 3). The neotype was figured by Howarth (1958, pl. 2, fig. 11).

NOMENCLATURE. Proposed by Howarth (1955 : 172) in substitution for the Nodifer Subzone of Spath (1942), because *Amaltheus nodifer* Buckman (1911*a* : 25*d*) is a synonym of *A. subnodosus*. The Depressus Zone of Frentzen (1934 : 43) is a senior synonym, for the index species *Ammonites amaltheus depressus* Quenstedt (1885, pl. 39, fig. 19) is pre-occupied. Includes the *boscense* and *acanthoides* hemerae of Buckman (1930 : 42).

STRATIGRAPHY. The subzone corresponds to the range of *Amaltheus subnodosus*. The zone index *Amaltheus margaritatus* first appears at the base of this subzone and soon becomes abundant.

In all British areas this subzone is well developed and fossiliferous ; *Amauroceras* and several species of *Amaltheus* occur but there are few or no representatives of other ammonite families. The subzone can be recognized in several areas of France and Germany. At Aveyron, Monestier's " subzones $a_2$ and b " (1915, 1928) belong to the Subnodosus Subzone ; Amaltheidae are abundant and include *Amaltheus gloriosus* Hyatt, which is very rare in Britain, and several species of *Protogrammoceras*, *Fuciniceras*, *Arieticeras*, *Prodactylioceras* and *Reynesoceras* are also common. In Swabia, Frentzen's " *nodifer* beds " (1937) belong to this subzone, and a rich fauna of typical Amaltheidae has been described.

### *Gibbosus Subzone*

(Pl. 71, fig. 2)

INDEX SPECIES. *Amaltheus gibbosus* (Schlotheim, 1820 : 66). The lectotype was figured by Howarth (1958 : 18, text-fig. 10).

NOMENCLATURE. As a hemeral index it dates from Buckman (1918 : 262) ; it was used as a zone by Kuhn (1935 : 465) and as a subzone by Spath (1942). Buckman's Laevis Zone (1920 : 68) is a synonym, for in its type area at Raasay, western Scotland, the range of *Ammonites amaltheus laevis* (Quenstedt, *non* Bruguière) (a synonym of *Amauroceras ferrugineum*) is the same as that of *Amaltheus gibbosus*.

STRATIGRAPHY. This subzone corresponds to the range of *Amaltheus gibbosus*.

At the lower boundary the index fossil does not overlap with the range of *A. subnodosus* and at the upper boundary it changes rapidly into the earliest species of *Pleuroceras*. Other common Amaltheidae in this subzone are *Amaltheus margaritatus*, *A.* (*Pseudoamaltheus*) *engelhardti* (d'Orbigny) and *Amauroceras ferrugineum*.

In Britain, Amaltheidae of this subzone are only common in the Hebrides, where they occur at approximately the middle of the Scalpa Sandstone Series (Howarth, 1956). In all English areas the beds are poor in ammonites, but sometimes *A. margaritatus* occurs fairly commonly alone (Howarth, 1955, 1957, 1958 : ix–xii).

In France and Germany, particularly at localities at Aveyron and in Swabia, this subzone is well developed with the characteristic Amaltheidae very common. Monestier's " subzone c " at Aveyron (1915, 1928) belongs to the Gibbosus Subzone, and, although ammonites of families other than Amaltheidae are not so common as in the Subnodosus Subzone, species of *Arieticeras* and *Paltarpites* also occur. In Swabia, Frentzen's " *margaritatus* beds " (1937) belong to this subzone.

## SPINATUM ZONE

(Pl. 71, fig. 1)

INDEX SPECIES. *Pleuroceras spinatum* (Bruguière, 1789 : 40). The neotype was figured by Howarth (1958, pl. 7, fig. 2).

NOMENCLATURE. Introduced by Oppel (1856 : 138). The zone includes part of the " Zone de l'*Ammonites acanthus* " of Collenot (1869 : 172) and the *argutus* and *spinatum* hemerae of Buckman (1930 : 41).

STRATIGRAPHY. The Spinatum Zone corresponds to the range of the genus *Pleuroceras*. *Pleuroceras transiens* Frentzen marks the lower boundary and the top is drawn where the Amaltheidae become extinct and are succeeded by an abundant fauna of Dactylioceratidae and Hildoceratidae. In several areas in the Midlands and on the Dorset coast *Dactylioceras directum* (Buckman) had already appeared alongside the last *Pleuroceras* at the top of the Spinatum Zone (Howarth, 1957 : 197–198). Subdivision is made according to the succession of species of *Pleuroceras*. Species of *Amaltheus*, *Pseudoamaltheus* and *Amauroceras* also occur as well as several genera of other families.

In Britain the rocks of this zone show very large differences in facies and thickness from one area to another. In Dorset, Somerset, the Cotswolds and the Midlands the zone consists of the Marlstone Rock Bed of varying thickness and somewhat varying lithology ; in Yorkshire it consists of most of the Ironstone Series, including the main iron-ore producing seams ; in the Hebrides it consists of roughly the upper 100 ft. of the Scalpa Sandstone. In the Aveyron area of France Monestier's " subzone d " (1915, 1928) belongs to the Spinatum Zone. In the Côte d'Or Collenot's Acanthus Zone (1869 : 172) belongs mainly to the Spinatum Zone, for it contains *Pleuroceras spinatum* and other Amaltheidae (Carré, 1876 : 132), but the upper part may belong to the Tenuicostatum Zone if this should prove to be the proper horizon of *Dactylioceras acanthus* (d'Orbigny).

### *Apyrenum Subzone*

(Pl. 71, fig. 5)

INDEX SPECIES. *Pleuroceras apyrenum* (Buckman, 1911*a* : 24*d*). The holotype was figured by Tate & Blake (1876, pl. 8, fig. 2) and Howarth (1958, pl. 6, fig. 1).

NOMENCLATURE. Introduced by Spath (1942) to supersede Frentzen's Bechteri Zone (1934 : 43), for *Amaltheus bechteri* Frentzen (1934 : 40) is a composite species consisting of both *Pleuroceras solare* (Phillips) and *P. salebrosum* (Hyatt) (see Howarth, 1958 : 30, 33). Includes the *lenticulare* and *regulare* hemerae of Buckman (1930 : 41–42).

STRATIGRAPHY. The commonest Amaltheid is *Pleuroceras solare* (Phillips), and the subzone is best defined as corresponding to the range of this species with the lower boundary extended down to include the first appearance of *Pleuroceras transiens* (Fentzen). In the upper half of the subzone *P. spinatum*, *P. apyrenum* and several other species occur. Other genera represented are *Amauroceras* (especially in Yorkshire), *Amaltheus* and *Pseudoamaltheus*.

In Britain this subzone is well developed, though in the Midlands and in the lower half in Yorkshire, ammonites are rare. In the Hebrides and many localities in west and south-west England the *Pleuroceras solare* fauna is abundant, but in Dorset this subzone is highly condensed and absent in places.

In Swabia Frentzen's "*bechteri* beds" (1937) belong to this subzone and contain the characteristic fauna in abundance. At Aveyron the Spinatum Zone is condensed and this subzone has not been separated. In other areas of France and Germany the presence of the subzone is known from numerous specimens of *Pleuroceras solare*.

### *Hawskerense Subzone*

(Pl. 71, fig. 4)

INDEX SPECIES. *Pleuroceras hawskerense* (Young & Bird, 1828 : 258, pl. 14, fig. 6). The type specimen was figured by Buckman (1923, pl. 408).

NOMENCLATURE. As a hemeral index it dates from Buckman (1922 : 453) and it was used as a subzone by Spath (1942). Includes the *paltus* hemera of Buckman (1930 : 41).

STRATIGRAPHY. Comprises approximately the upper half of the Spinatum Zone, the lower boundary being drawn immediately above the highest *Pleuroceras solare*. There are many Amaltheidae, but representatives of other families are rare. In the top half the incoming *Dactylioceras* fauna (especially *D. directum* (Buckman) and allied species) is found in some places.

In Britain the fauna is highly differentiated : in Yorkshire *P. hawskerense* is abundant, together with *Amauroceras ferrugineum* and *Amaltheus reticularis* (Simpson) ; in the Cotswolds, Somerset and Dorset *P. yeovilense* Howarth and large examples of *P. spinatum* are characteristic, and *P. apyrenum* is also present ; in the Hebrides *P. spinatum* occurs alone.

In France and Germany the subzone can be recognized by the presence of *P. spinatum* and *P. hawskerense* above the range of *P. solare*. It comprises Frentzen's "*spinatus* beds" (1937) in Swabia, but it has not been separated at Aveyron. In North-west Germany *Pseudoamaltheus engelhardti* (d'Orbigny) probably ranges up into this subzone, but its limits have not been determined accurately (Kumm, 1941).

## TOARCIAN STAGE

The following two zones were included in the Toarcian by Oppel (1856 : 196) :

2. Zone of *Ammonites jurensis*
1. Zone of *Posidonia bronni*

The base of the Bronni Zone was drawn immediately above the highest *Pleuroceras* and below the first appearance of *Dactylioceras* in abundance. The top of the Jurense Zone was drawn between the faunas of *Pleydellia aalensis* below and *Leioceras opalinum*, at the base of the Bajocian, above.

### *Whitbian and Yeovilian Substages*

The names Whitbian and Yeovilian were first introduced as "Ages" by Buckman (1910 : 88) to provide a means of subdividing the Toarcian Stage. They have found some favour since then as substages and their use as such is often convenient, but some redefinition of their limits is necessary. When founding the term Whitbian on the succession in the neighbourhood of Whitby, Yorkshire, Buckman proposed that it should cover the strata which, in the present paper, constitute the Tenuicostatum to Variabilis Zones inclusive, claiming that all these were developed near Whitby. In practice the Variabilis Zone is not known from either Whitby or the neighbouring cliff sections, being cut out by the unconformity at the base of the overlying Dogger (Lower Bajocian). All these localities are situated north-west of the important Peak Fault, and the Variabilis Zone, together with the succeeding Toarcian strata, is fully developed only at Blea Wyke, about six miles south-east of Whitby, where a radically different succession is found on the south-eastern side of the Peak fault. The line separating Whitbian from Yeovilian should, then, be drawn between the Bifrons and Variabilis Zones as interpreted in this paper, forming a convenient demarcation between the disappearance of *Hildoceras*, perhaps the best known of all the Whitby ammonites, and the appearance of the Phymatoceratinae.

The type section of the Yeovilian lacks the precision of the Whitbian succession, being defined merely as "the Somerset–Dorset district", though presumably at or near Yeovil. In its original usage (Buckman, 1910 : 88) the Yeovilian comprised the present Striatulum to Moorei Subzones inclusive, but if the top of the Whitbian is to coincide with the top of the Bifrons Zone then the Yeovilian should commence with the Variabilis Zone. At Barrington the base of the Yeovil Sands (Dispansum Subzone) is underlain by 6 in. of black clays which apparently represent a condensed sequence (Spath *in* Buckman, 1922 : 449). The fauna includes *Hildoceras, Haugia, Grammoceras, Pseudogrammoceras* and *Hammatoceras*, and indicates the presence of

horizons ranging from the Bifrons Zone (*pars*) to the Struckmanni Subzone. Therefore the Variabilis Zone is represented in the type area of the Yeovilian.

To follow Buckman rigidly in drawing the upper limit of the Yeovilian between the Moorei and Aalensis Subzones would be to isolate the latter within the upper part of the succession which, by original definition, must necessarily be included in the Toarcian Stage. The separation of the two is also unjustified on palaeontological grounds as they both contain *Dumortieria* in certain European districts. The evidence for the existence of the Aalensis Subzone near Yeovil is well established, and at Haselbury Mills thin blue clays and marls with a typical ammonite fauna are overlain unconformably by Upper Inferior Oolite (Kellaway & Wilson, 1941 : 147). It is noteworthy that Buckman, in his earlier works, did not recognize an Aalensis horizon and placed the " *Moorei*-Beds " of the Cotswolds immediately below the *Opalinum* Beds or Zone, from which he recorded *Grammoceras aalense* (Buckman, 1889 : 463). In addition Buckman (1889 : 451) recorded *Grammoceras aalense* from the " Moorei- and Dumortieria-Beds " in the " Yeovil or Bridport Sands " of Burton Bradstock, and he later (1910 : 89) argued that the top of the Yeovilian ended appropriately with the " finish of the Yeovil Sands ". The borehole at Stowell, about three miles north of Milborne Port, has shown that the topmost 5 ft. of the Yeovil Sands belong to the Aalensis Subzone (Kellaway & Wilson, 1941 : 147–148). Thus the inclusion of the Aalensis Subzone at the top of the Yeovilian is borne out by geological evidence from the type area.

### *Aalenian " Stage "*

Aalenian has frequently been used as a stage or substage to include some part of the Upper Lias. At its original proposal by Mayer-Eymar (1864) the beds included were the " Couches de Boll ou à l'*Amm. torulosus* " at the base, up to the " Couches de Giengen ou à l'*Amm. sowerbyi* " at the top ; it was immediately underlain by the " Couches de Heiningen ou à l'*Amm. jurensis* " at the top of the Toarcian. Later Mayer-Eymar (1881) made it clear that what he meant by the beds with *Amm. torulosus* and *Amm. jurensis* were the Torulosus and Jurense Zones as defined by Oppel (1856). Therefore the base of the Aalenian is drawn between Oppel's Torulosus and Jurensis Zones, i.e. between the Opalinum and Jurense Zones of modern nomenclature, and it coincides with the base of the Bajocian. From the original definitions of these zones, the Aalenian does not, therefore, include the subzone of *Pleydellia aalensis*. Attempts to place the base of the Aalenian at different levels by Renevier, Choffat, Toucas, Buckman and especially Haug's supposed adoption (1892, 1910 : 954) of " l'étage Aalénian dans le sens primitif ", cannot be entertained. Thus the Aalenian cannot be used to include any part of the Lias.

### *Bronni Zone*

*Posidonia bronni* cannot be used as an index in any scheme of ammonite zones of the Lias, and Oppel himself (1856 : 197) suggested that *Ammonites serpentinus* might be a more satisfactory index. A second alternative index, *Ammonites communis*, was proposed by Wright (1858 : 25), to be superseded later by *Ammonites bifrons*.

The first division of the Bronni Zone was by Reynès (1868 : 63) into a Serpentinus Zone below and a Bifrons Zone above, and finally a third zone of *Ammonites annulatus* was added by Tate & Blake (1876 : 16) below the Serpentinus Zone. This three-fold division of the original Bronni Zone into Bifrons, Serpentinus and Annulatus Zones has proved satisfactory and applicable throughout the province ; subsequent changes in nomenclature alone have now given us the Bifrons, Falcifer and Tenuicostatum Zones, equivalent in every way to the original zones.

### *Jurense Zone*

Oppel's zone of *Pachylytoceras jurense* included ammonites from *Haugia variabilis* at the base up to *Pleydellia aalensis* at the top, and this made the Jurense Zone of roughly the same size as his Bronni Zone. Subdivision of the Jurense Zone has always been made on ammonites other than Lytoceratidae, and a scheme which has since been found to be applicable throughout the province was progressively elaborated by Buckman, mainly on the basis of observations on the Cotswolds Upper Lias, into the seven divisions : *variabilis*, *striatulum*, *struckmanni*, *dispansum*, *Dumortieria* sp., *moorei* and *aalensis* (Buckman, 1898, Table I, p. 450) (for reasons given below *lilli* is rejected). These were used as subzones of a large Jurense Zone by Spath and Arkell. In Swabia *P. jurense* is common, especially in the middle part of the Jurense Zone, and it ranges up as far as the Aalensis Subzone (Pompeckj, 1896 : 141), but it is much less common elsewhere in Germany and France, and distinctly rare in Britain. Apart from the lack of exact knowledge of the range of *P. jurense*, it would clearly be better to base the zonal and subzonal indices on the same groups of ammonites. At the same time it would be as well to reduce the large size of the Jurense Zone by using several indices in its place. It is now proposed to use three zones with subzones grouped as shown in the Table (p. 441).

### *Lilli " Subzone "*

The *lilli* hemera was introduced by Buckman (1898, Table on p. 450 ; 1898*a* : xii–xiii) as an horizon between *bifrons* below and *variabilis* above. It has been accepted as a valid subzone at the base of the Jurense Zone by Arkell (1933 : 165 ; 1956 : 35) and at the top of the Bifrons Zone by Spath (1942 : 266).

Buckman surmised that by the principle of recapitulation *Haugia* was a descendent of *Lillia*, and therefore *Lillia* must be older (1890 : 145). As *Lillia* is rare in Britain and absent from the Cotswolds he then proposed to recognize the *lilli* horizon in the Cotswolds Sands by its main " contemporary " (i.e. occurring immediately below *Haugia*) ammonite, *Hildoceras semipolitum* Buckman (1898*a* : xiii ; Richardson, 1910 : 115–116). Associates of *H. semipolitum* are species of *Pseudolioceras*, *Dactylioceras* and *Catacoeloceras* and this is the highest fauna of the Bifrons Zone. Buckman's only record of a true *Lillia* (Buckman & Wilson, 1896 : 687) is from an horizon above the lowest *Haugia*. *Lillia* and *Denckmannia* are now held to be synonyms of *Phymatoceras* and its subgenus *Chartronia*, and Buckman's records of these forms in the lower

part of the Cotswolds Sands are all associated with *Haugia* of the Variabilis Zone. The earliest *Haugia* appears before *Phymatoceras*, just the reverse of Buckman's surmise on recapitulation theory.

In Yorkshire, Dean (1954 : 170–171) found that the only *Phymatoceras* recorded, *P. fabale* (Simpson), almost certainly came from the Variabilis Subzone, in association with *Haugia*. The beds containing *Catacoeloceras* that he referred to the Lilli Subzone should be included in the Braunianus Subzone.

In eastern France Mouterde (1953 : 417) found that a Lilli Subzone was not separable, and in Swabia Krumbeck (1944 : 3) was able to show that *Phymatoceras* occurred in the upper half of the Variabilis Zone.

Thus the Lilli Subzone is a synonym of the Variabilis Zone.

## LOWER TOARCIAN OR WHITBIAN SUBSTAGE
## TENUICOSTATUM ZONE

(Pl. 72, fig. 1)

INDEX SPECIES. *Dactylioceras tenuicostatum* (Young & Bird, 1822 : 247, pl. 12, fig. 8). The neotype was figured by Buckman (1920*a*, pl. 157).

NOMENCLATURE. Introduced by Buckman (1910 : 85) to supersede Tate & Blake's Annulatus Zone (1876 : 168) whose index species had been misidentified. Recently Sylvester-Bradley (1958 : 67–68) has shown that *Ammonites annulatus* J. Sowerby is a *Catacoeloceras* of the Bifrons Zone. The Tenuicostatum-Semicelatum Zone of Maubeuge (1948 : 59 ; 1957 : 189) and the Semicelatum Zone of Maubeuge (1952 : 365) are synonyms. Includes the upper part of the Acanthus Zone of Collenot (1869 : 172), the Zone of *Harpoceras schroederi* and *Lytoceras siemensi* of Denckmann (1893), Bode (1905) and Stolley (1909), and the *helianthoides*, *directus*, *Tiltoniceras* and *tenuicostatus* hemerae of Buckman (1930 : 41).

STRATIGRAPHY. The base of the zone is drawn at the first appearance of *Dactylioceras* in abundance after the disappearance of *Pleuroceras*, and in some areas in Britain this coincides with the appearance of *Tiltoniceras acutum* (Tate). The top is limited by the appearance of *Elegantuliceras* and *Harpoceras*.

In the type area of Yorkshire the zone comprises the stratigraphical division the Grey Shales, which is about 30 ft. thick. Careful collecting in the Grey Shales has enabled four horizons to be recognized as follows (kindly supplied in advance of publication by Prof. P. C. Sylvester-Bradley) :

4. *Dactylioceras semicelatum* horizon
3. *D. tenuicostatum* horizon
2. *Dactylioceras* sp. nov. horizon
1. Unfossiliferous beds (1 specimen of *Protogrammoceras* found)

These horizons have not yet been recognized anywhere else in the province. In Lincolnshire the zone consists of 15 ft. of shales, but farther south in the Midlands it is much thinner.

In parts of Oxfordshire, Leicestershire and Lincolnshire the base of the Tenuicostatum Zone is marked by a Transition Bed containing two characteristic ammonites,

*Tiltoniceras acutum* and *Dactylioceras directum* (Buckman). This was called the *acutum* hemera by Buckman (1898, Table I, p. 450) and the Acutum Zone by Walford (1899 : 33). It is probably equivalent to the lowest horizon in the Grey Shales of Yorkshire and there is some evidence that it is present in the Junction Bed of the Dorset coast (*At* layer, Jackson, 1926 : 497–498). However, the limited geographical distribution of *Tiltoniceras acutum* does not warrant the separation of an Acutum Subzone.

In other British areas the Tenuicostatum Zone has not been separated, but it cannot be more than 2 or 3 ft. thick anywhere.

The zone has been recognized in exposures and borings over much of the Paris basin, eastern France, and Luxemburg, where the characteristic species of *Dactylioceras* are very common (Maubeuge, 1948, 1952, 1957 ; Mouterde, 1953 : 416 ; Collenot, 1869 ; Carré, 1876). At Bettembourg the thickness reaches 15–16 ft., and at many other places it is 10 ft. thick. The terms Semicelatum Zone and Semicelatum-Tenuicostatum Zone have been widely used in France, but both are junior synonyms of the correct name, Tenuicostatum Zone. The upper part of the " Acanthus Zone " of Collenot (1869 : 172) probably belongs to the Tenuicostatum Zone, but the exact horizon of *Dactylioceras acanthus* (d'Orbigny) is not known. *Tiltoniceras* has not been found in France or Luxemburg.

In north Germany the zone is known from boreholes to be at least 16 feet thick. From these and several surface exposures *Tiltoniceras schroederi* (Denckmann) and characteristic Tenuicostatum Zone species of *Dactylioceras* have been obtained (Hoffmann & Martin, 1960). This was Denckmann's horizon (1893) of *Harpoceras schroederi* and *Lytoceras siemensi*, which was used as a zone by Stolley (1909). In Swabia the zone is also present but probably much thinner, and the ammonites have yet to be collected in detail (Hoffmann & Martin, 1960 : 136).

## FALCIFER ZONE

(Pl. 72, fig. 3)

INDEX SPECIES. *Harpoceras falcifer* (J. Sowerby, 1820 : 99, pl. 254, fig. 2). The holotype was figured by Buckman (1928, pl. 764).

NOMENCLATURE. Oppel (1856 : 197) first suggested that *Ammonites serpentinus* Reinecke might form a better index species for his zone of *Posidonia bronni*, although he continued to use the latter. The Serpentinus Zone was subsequently restricted by the recognition of the Bifrons Zone above and the Tenuicostatum Zone below. Haug (1885 : 619) first proposed that *Harpoceras falcifer* be used as the index species instead of *H. serpentinum* on the grounds that most of the records of the latter were misidentifications of *H. falcifer*. Buckman and Arkell both accepted *H. falcifer* as the zonal index, but Spath (1942) reverted to *H. serpentinum* for reasons of priority. However, with the establishment of *H. falcifer* as the type species of *Harpoceras* and the reference of *Ammonites serpentinus* to the genus *Hildaites*, it is clear that *H. falcifer* is the only satisfactory zonal index, for *Harpoceras* is the characteristic genus of the zone.

STRATIGRAPHY. The zone corresponds to the combined stratigraphical ranges of the genera *Elegantuliceras* and *Harpoceras*. The only record of *Harpoceras* occurring in the Bifrons Zone above is Mouterde's *H. falcifer* (1953 : 417), claimed to occur in beds also yielding *Hildoceras bifrons* in eastern France, but in the absence of a figured specimen this cannot be checked, and it may be due to condensation. Several species of *Dactylioceras* and allied genera are present throughout the zone.

The subzones discussed below have been determined from the sequence in Britain. In North Germany several smaller divisions have been proposed which can be correlated exactly with the succession in Yorkshire. In Swabia and France the subzones have not been separated, but the zone as a whole and the characteristic ammonites are well developed, particularly in the *Posidonia* Shales of the Swabian Alb.

### *Exaratum Subzone*

(Pl. 72, fig. 2)

INDEX SPECIES. *Harpoceras exaratum* (Young & Bird, 1828 : 266). The holotype was figured by Buckman (1909, pl. 5).

NOMENCLATURE. Introduced by Buckman (1910 : 86, 88 ; 1910*a* : xvi) as a zone between the Tenuicostatum and Falcifer Zones. It was relegated to a subzone of the Falcifer Zone by Arkell (1933) and Spath (1942). The Latescens Zone of Thompson (1910 : 462–463) is a synonym. It was based on the misidentification of a *Hildaites*, because *Ammonites latescens* Simpson is now known to be a *Pseudogrammoceras* of the Struckmanni Subzone in Yorkshire (Buckman, 1913, pl. 79 ; Dean, 1954 : 168). The zones of *Harpoceras capillatum*, *Harpoceras elegans*, and *Harpoceras boreale* used by Denckmann (1893), Bode (1905) and Stolley (1909) are synonyms.

Includes the *Elegantuliceras*, *Eleganticeras*, Grantham Ammonite, *exaratum*, *Harpoceratoides* and *crassoides* hemerae of Buckman (1930 : 39–40).

STRATIGRAPHY. The subzone corresponds to the combined stratigraphical ranges of *Elegantuliceras* and *Harpoceras exaratum*. In Yorkshire it consists of the Jet Rock, 25 ft. thick, and these ammonites occur in the following sequence :

2. *Harpoceras exaratum* and spp.
1. *Elegantuliceras* spp.

Species of *Hildaites* and *Harpoceratoides*, and *Monestieria erratus* (Simpson) also occur, mainly in the upper horizon. The latter species was wrongly referred to the genus *Pseudolioceras* by Buckman (1920*a*, pl. 188) ; the earliest British *Pseudolioceras* occurs in the Fibulatum Subzone.

At Grantham 15 ft. of shales contain *H. exaratum* and an undescribed species of *Elegantuliceras* (Buckman's " Grantham Ammonite "), but information as to the stratigraphical relation of these two species is lacking. In the Junction Bed of Dorset those layers yielding species of *Harpoceratoides* probably belong to this subzone. In other British areas, e.g. in the Stowell Park Borehole (Spath, 1956 : 143), the horizons in Yorkshire are not known to be separable, but the subzone as a whole is widely distributed and recognizable.

In Lower Saxony, North-west Germany, the lower part of the Upper Lias contains four layers of calcareous nodules in 4–5 ft. of shales, overlying 2 ft. of unfossiliferous beds on top of the Middle Lias. Ammonites obtained from the nodules led to the establishment of the following sequence of horizons by Denckmann (1887, 1893 : 109) and Bode (1905 : 219–220), used later as zones by Stolley (1909 : 287), Kumm (1941 : 236, 262–264) and Hoffmann (1949 : 115) :

4. Horizon of *Hildaites borealis* (Seebach)
3. Horizon of *Elegantuliceras* " *elegans* (Sowerby) " as figured by Denckmann (1887 : 58, pl. 4, fig. 5)
2. Horizon of *Elegantuliceras capillatum* (Denckmann)
1. Horizon of *Tiltoniceras schroederi* (Denckmann) and *Lytoceras siemensi* (Denckmann)

Horizon 1 belongs to the Tenuicostatum Zone and has been discussed above (p. 477). The position of *Harpoceras exaratum* is not clear, but from Bode's description of the succession (1905 : 219–220) it probably occurs in the shales between horizons 3 and 4, and in the 2–3 ft. of shale overlying horizon 4. In addition *Polyplectus subplanatus* (Oppel) and *Monestieria goslarensis* (Schloenbach) occur in horizon 4, and species of *Dactylioceras* occur throughout. This succession is exactly the same as that found in Yorkshire, and the sequence of *Elegantuliceras* followed by *Harpoceras exaratum* seems to be well established in the Yorkshire–North German basin.

### *Falcifer Subzone*

(Pl. 72, fig. 3)

Index species and Nomenclature. See Falcifer Zone. The use of the same index for both zone and subzone is unavoidable in this case. Synonyms are the Ovatum (or Pseudovatum) Zone of Buckman (see below) and the zone of *Harpoceras capellinum* of Denckmann (1893) and Stolley (1909). Includes the *crenatum, murleyi, anguiformis, anguinum, Hildaites, falciferum, tardum, facula, metorchion, Hildoceratoides, Harpocerate, pseudovatum, vermis* and *lobatum* hemerae of Buckman (1930 : 39–40).

Stratigraphy. The lower limit is drawn at the first appearance of *Harpoceras falcifer*, which is not known to overlap with *H. exaratum*, and the top is limited by the appearance of *Hildoceras bifrons*.

In Yorkshire the subzone consists of the Bituminous Shales, containing the index species throughout, together with the overlying Ovatum Band, in all about 70 ft. of beds. Buckman (1910 : 85–87) introduced *Ammonites ovatus* Young & Bird, 1828 *non* 1822, as a zone index for the Ovatum Band. Later Buckman (1910*a* : xvi) substituted the name *pseudovatum*, which remained a *nomen nudum* until both the Young & Bird specimens were figured by Buckman in 1918 (1918*a*, pls. 111A–C), and the genus *Ovaticeras* proposed. *Ovaticeras* is confined to the Ovatum Band in Yorkshire, and elsewhere it is very rare, being known only from a few specimens in the Midland counties. This distribution is too restricted for the recognition of an Ovatum Subzone.

In the Midlands and South-west England the subzone is developed almost everywhere in clay or Cephalopod Bed facies, and it is present in the Junction Bed of Dorset. Associations of *H. falcifer* and *Hildoceras bifrons* in some of the Cephalopod Beds are due to condensation, for these species are stratigraphically separate in the clay facies. Spath (1942 : 268) claimed that two horizons were recognizable : the upper with *Hildaites serpentinus* and the lower with *Elegantuliceras* sp. nov. (Buckman's " Grantham Ammonite "). This is not correct, for *H. serpentinus* is not known to characterize any particular horizon in the Falcifer Subzone, and Buckman's " Grantham Ammonite " comes from the Exaratum Subzone.

*Orthildaites* and *Hildaites* occur in this subzone, large specimens of *Hildaites serpentinus* (Reinecke), as interpreted by Buckman, and related species being particularly common in the Barrington–Ilminster area of Somerset. *Polyplectus subplanatus* (Oppel) has been recorded by Thompson (1910 : 464) from Northamptonshire and is the earliest record of this genus in Britain ; *Pseudolioceras lythense* (Young & Bird) recorded from Aveyron (Monestier, 1922 : 324) is the earliest *Pseudolioceras*.

Overlying the Exaratum Subzone (with its upper limit drawn 2–3 ft. above the horizon of *Hildaites borealis*) in Lower Saxony are 10–15 ft. of shales containing a hard marl band. These shales have been called the horizon of *Harpoceras capellinum* (Schlotheim) by Denckmann (1893 : 109) and Bode (1905) ; this was used later as a zone by Stolley (1909), Kumm (1941) and Hoffmann (1949). As well as *Polyplectus* [*Harpoceras*] *capellinus*, *Harpoceras falcifer* is very common, especially in the marl band, and *Hildaites serpentinus* (Reinecke), other species of *Hildaites*, and Dactylioceratidae also occur. This is clearly a Falcifer Subzone assemblage.

## BIFRONS ZONE

(Pl. 72, fig. 4)

INDEX SPECIES. *Hildoceras bifrons* (Bruguière, 1789 : 40). The neotype (? holotype) was figured by Buckman (1918*a*, pl. 114A).

NOMENCLATURE. This species was first introduced as an index-fossil by Eudes-Deslongchamps (1864 : 74) for his " Couches à *Ammonites bifrons* et *serpentinus* " in Normandy. Reynès (1868 : 68) recognized the stratigraphical separation of these two ammonites and placed the " Zone à *A. bifrons* " between the Jurense Zone above and the " Serpentinus " Zone below.

The Commune Zone has long been used as a term synonymous with the Bifrons Zone. At its first introduction (Wright, 1858 : 25 ; 1863 : 53), however, the Commune Zone was made equivalent to Oppel's Bronni Zone (= Tenuicostatum + Falcifer + Bifrons Zones), and it was Tate & Blake (1876 : 16) who first restricted it to the beds between the Jurense and " Serpentinus " Zones. It is now known that the true *Dactylioceras commune* is restricted to the lower part of the range of *Hildoceras bifrons*, and in this sense it is used below as a subzonal index.

The Complanatus Zone of Collenot (1869 : 190) is a synonym ; it was used instead of the Bifrons Zone because *Hildoceras bifrons* was said to be rare in the area Collenot (1869 : 194–195) was describing.

STRATIGRAPHY. The zone corresponds to the stratigraphical range of *Hildoceras* (s.s.), i.e. excluding *Hildaites* and " *Hildoceratoides* " which occur earlier. The true *Hildoceras* is not known outside the zone.

All attempts at subdivision of the Bifrons Zone have been based largely on faunas of Dactylioceratidae, even though various genera of this family, and even *Dactylioceras* itself, range from the base of the Toarcian up to the Variabilis Zone. The divisions followed by Buckman, Spath and Arkell were introduced by Thompson (1910) ; these are accepted here, with the substitution of *Dactylioceras commune* as the index for the lowest subzone. The result is a scheme of three subzones founded on successive faunas of Dactylioceratidae and these have proved satisfactory at all places in the province where the succession is not too condensed for the faunas to be separated. Limitation of the top and bottom of the Bifrons Zone must still be based on the *Harpoceras-Hildoceras-Haugia* sequence.

The subzones can be applied in Yorkshire, the Midlands, a few places in South-west England, much of the eastern part of the Paris basin, and in Lorraine (Corroy & Gérard, 1933), but they have yet to be recognized in southern France (Aveyron), Swabia (where the *Posidonia* Shales belong partly to this zone) and North-west Germany.

### *Commune Subzone*

(Pl. 72, fig. 5)

INDEX SPECIES. *Dactylioceras commune* (J. Sowerby, 1815 : 10, pl. 107, figs. 2, 3). The lectotype was figured by Arkell (1956, pl. 33, fig. 4).

NOMENCLATURE. It was introduced by Wright as " Communis-Bed " (1858 : 25) and used later as Communis Zone (Wright, 1863 : 53, 86). It was originally employed for all the Toarcian below the Jurense Zone, it was then used as an alternative index to *Hildoceras bifrons*, but it was finally abandoned by most workers as an index species in favour of the latter. Thompson (1910 : 464) used the alternative terms " Communis Beds, or Subcarinata Zone ", and thereafter *Frechiella subcarinata* was accepted as a subzonal index. The reasons for reverting to *D. commune* are first, priority, secondly, all the subzones of the Bifrons Zone are now based on Dactylioceratidae, and thirdly, *Frechiella* is always rare, and is therefore not suitable for a subzonal index.

It includes the *subcarinata*, *athleticum* and *bifrons* hemerae of Buckman (1930 : 39).

STRATIGRAPHY. The subzone corresponds to the range of *D. commune* and *D. athleticum* (Simpson), limited at the top by the incoming of species of *Peronoceras*. Other species and genera of Dactylioceratidae occur, but none with the distinctive ribbing of *Peronoceras*. No authentic records of *D. commune* are known from beds higher than the Commune Subzone, though closely related species of *Dactylioceras* do occur higher. *Hildoceras bifrons* is abundant, but the genera *Hildaites*, *Harpoceratoides* and *Harpoceras* are no longer present. All records of the latter genus prove to be *Polyplectus*.

Owing to the abundance of the index species the subzone is widely recognizable in Britain and France. In Yorkshire *D. commune* and *D. athleticum* range from

the Hard Shales overlying the Ovatum Band up to the appearance of *Peronoceras*, giving a thickness of about 45 ft. The thickness is similar in the north Midlands. To the south-west the subzone has not been separated, although the index species occurs widely. In Somerset and Dorset it is represented in Junction and Cephalopod Beds.

South and east of the Paris basin and in Lorraine *D. commune* occurs abundantly and the subzone attains considerable thickness (Mouterde, 1953 : 417 ; Corroy & Gérard, 1933 : 200–201). In North Germany the subzone has not been separated, although *Frechiella brunsvicensis* Stolley occurs in the lower part of the Bifrons Zone (Hoyer, 1904 : 387–389).

### *Fibulatum Subzone*

(Pl. 73, fig. 2)

INDEX SPECIES. *Peronoceras fibulatum* (J. de C. Sowerby, 1823 : 147, pl. 407, fig. 2). A topotype was figured by Buckman (1926, pl. 683).

NOMENCLATURE. Introduced by Thompson (1910 : 462). The subzone of *Porpoceras subarmatum* of Corroy & Gérard (1933 : 200) is a synonym.

STRATIGRAPHY. Corresponds to the range of *Peronoceras*, being limited at the top by the first appearance of *Zugodactylites*. Both thin-whorled and thick-whorled (" *Porpoceras* ") species of *Peronoceras* occur and also species of *Dactylioceras* (but not *D. commune*) and *Catacoeloceras*. *Hildoceras bifrons* is common and in this subzone the first British *Pseudolioceras* occurs, *P. lythense* (Young & Bird).

The thickest development of this subzone is 76 ft. of clay in Northamptonshire. It can also be separated at Grantham (Trueman, 1918 : 107) and in Yorkshire (Dean, 1954), but it has yet to be recognized in South-west England. In eastern France Mouterde (1953) did not separate it from the overlying Braunianus Subzone, although it is well developed and fairly thick in Lorraine where Corroy & Gérard (1933 : 201) recorded the characteristic *Peronoceras* fauna, and called it the subzone of *Peronoceras subarmatum*. It has yet to be recognized in Germany.

### *Braunianus Subzone*

(Pl. 73, fig. 1)

INDEX SPECIES. *Zugodactylites braunianus* (d'Orbigny, 1845 : 327, pl. 104, figs. 1–3).

NOMENCLATURE. Introduced as used here by Thompson (1910 : 461). Previous uses of this ammonite as the index for a stratal term at Aveyron by Reynès (1868), Nicklès (1907) and Monestier (1922) are discussed below. The subzone of *Coeloceras crassum* of Corroy & Gérard (1933 : 200) is a synonym in part, but it includes also ammonites of the Variabilis Zone.

Includes the *braunianus*, *vigoense*, ? *subplanatum* and *semipolitum* hemerae of Buckman (1930 : 38).

STRATIGRAPHY. The lower boundary is drawn between the latest *Peronoceras*

and the earliest *Zugodactylites braunianus*, and the upper boundary between the latest abundant *Hildoceras* and the earliest abundant *Haugia* and *Phymatoceras* faunas. In many areas *Z. braunianus* is characteristic of at least the lower part of the subzone. Species of *Catacoeloceras* are also common and characteristic, particularly in the higher part, but this genus is also common in the Variabilis Zone above. *Hildoceras bifrons* (including *H. " hildense "* Young & Bird sp.) and *H. semipolitum* Buckman are common in many areas, the latter species being confined to this subzone. Species of *Pseudolioceras* are also present. In several areas towards the south of the province a few *Haugia* and *Phymatoceras* appear in the upper half of this subzone while *Hildoceras* is still abundant, and similarly early examples are known in the Mediterranean Province. These are better regarded as rare forerunners of the Variabilis Zone Phymatoceratinae rather than abundant lingering *Hildoceras* faunas in the Variabilis Zone.

In Britain the index species is found only in Northamptonshire where it characterizes 70 ft. of clays. In Yorkshire the subzone is interpreted as comprising the beds between the highest *Peronoceras* and the lowest *Haugia*, and it includes the beds containing *Catacoeloceras* which were referred to the " Lilli Subzone " by Dean (1954 : 170–171) ; *H. bifrons* is present throughout. The lower part of the Cotswolds Sands contains *Hildoceras semipolitum* at levels consistently lower than the lowest *Haugia* and higher than *H. bifrons*, but Dactylioceratidae have yet to be found in these beds. At other localities in South-west England the Bifrons Zone is condensed in Junction Bed or Cephalopod Bed facies and this subzone is not separable.

In Lorraine Corroy & Gérard (1933 : 201–203) recorded a mixture of Braunianus Subzone and Variabilis Zone species from a phosphatic nodule bed above beds with *Peronoceras* ; this they called the subzone of *Coeloceras crassum*. In eastern France this subzone has not been separated from the Fibulatum Subzone, although in places the three ammonites *Hildoceras semipolitum, Zugodactylites braunianus* and *Catacoeloceras* sp. appear to be associated (Mouterde, 1953).

In the Aveyron district of southern France Reynès (1868 : 65–67) followed by Nicklès (1907 : 578–579) divided what they called the Bifrons Zone into three parts as follows (additions from Monestier's details (1922 : 324–327)) :

3. *Catacoeloceras crassum* (abundant), *Phymatoceras erbaense* (Hauer), *Dactylioceras* spp. and *Pseudolioceras* spp.
2. *H. bifrons* (abundant), *Phymatoceras erbaense* (rare), *Catacoeloceras crassum, Dactylioceras* spp. and *Pseudolioceras* spp.
1. *Z. braunianus, Peronoceras* spp., *Frechiella subcarinata, Catacoeloceras crassum, H. bifrons, Dactylioceras* spp., *and Praehaploceras zwieselei* (Monestier)

Many of these ammonites were figured by Monestier (1931), though unfortunately not those referred to as *H. bifrons*. *Z. braunianus* was said to be characteristic of division 1 and this was called the " Braunianum Subzone " by Monestier (1922 : 326) ; but it is clear from the list of species that division 1 contains almost the whole of the Bifrons Zone, and therefore Monestier's use of the term " Braunianum Sub-

zone" is a synonym of Bifrons Zone. Division 2 contains abundant *Hildoceras* (recorded as *H. bifrons*, but they may well be *H. semipolitum*) together with *Catacoeloceras* and rare early *Phymatoceras*; this is the upper half of the Braunianus Subzone. Division 3, in which *Hildoceras* is no longer present but *Phymatoceras* fairly common, belongs to the Variabilis Zone.

This subzone has not been recognized in Germany.

## UPPER TOARCIAN OR YEOVILIAN SUBSTAGE
## VARIABILIS ZONE

(Pl. 73, fig. 4)

INDEX SPECIES. *Haugia variabilis* (d'Orbigny, 1845 : 350, pl. 113, figs. 1–4).

NOMENCLATURE. First used by Buckman (1888 : 45, 46, 50) as a subzone within the Jurense Zone, underlain by the Bifrons Zone. It was later employed by Welsch (1903 : 821) as a zone but has since reverted to a subzone constituting the basal subdivision of the Jurense Zone (Spath, 1942 : 265). Synonyms are : Mucronatus Zone of Collenot (1869 : 190) ; Buckman's (1925 : 75) Haugian Age, comprising the *lilli, malagma, variabilis, grandis* and *pauper* hemerae ; Variabilis Zone plus Lilli Zone of Arkell (1930, Table facing p. 410) ; Variabilis-Schichten of Krumbeck (1943 : 281). The zone includes both " Banke des *Harpoceras doerntense* und *H. navis*" and " Banke des *Harpoceras illustre*" (Denckmann, 1893 : 109), names which were used later as zones by Stolley (1909).

STRATIGRAPHY. The lower limit of the zone is defined by the appearance of Phymatoceratinae in abundance, especially *Haugia* which is abundant throughout the zone, and the upper limit is drawn immediately below the first occurrence of *Grammoceras*. The incoming of the Phymatoceratinae coincides with the disappearance of *Hildoceras* in Britain, though the two are occasionally found together in the upper half of the Braunianus Subzone in some areas of France.

The fauna is well developed throughout the province and includes, in addition to *Haugia*, ammonites previously referred to *Denckmannia*, *Lillia* and *Pelecoceras*. All these are now placed in *Phymatoceras* or its subgenus *Chartronia* (Donovan, 1958 : 54 ; see also rejection of " Lilli Subzone " earlier in this paper, p. 475). The last Dactylioceratidae occur in this zone, species of *Dactylioceras* and *Catacoeloceras*, especially forms resembling *C. crassum* (Young & Bird), being very common at some localities in Swabia (Krumbeck, 1944 : 3) and at Aveyron (see p. 483). In Britain similar Dactylioceratidae are present in some exposures of the Variabilis Zone in the lower Cotswolds Sands (Buckman, 1889 : 444), but in Yorkshire they have not been found higher than the Braunianus Subzone, in strata which were previously assigned to the " Lilli Subzone " by Dean (1954 : 177). Other genera present include the long-ranging *Pseudolioceras*, and in Yorkshire the middle of the zone marks the upper limit of *Phylloceras heterophyllum* (J. Sowerby) (Dean, 1954 : 170). The genus

*Whitbyiceras*, type-species *W. pingue* (Simpson), was assigned by Buckman (1913 : 80*b*) to the Variabilis Zone on account of its supposed relationship to *Brodieia* [= *Brodiceras*]. *Whitbyiceras pingue* belongs, however, to the Harpoceratinae and was originally described from the Exaratum Subzone, whereas *Brodieia* is a characteristic member of the Phymatoceratinae from the Variabilis Zone in the Cotswolds and Somerset, and is also recorded widely elsewhere in Europe.

In Britain fossiliferous developments are found in the Peak Shales of Yorkshire, the lower Cotswolds Sands of the Cotswolds, and in condensed limestone sequences in Somerset and Dorset. The zone is absent throughout the Midlands.

In north-western Germany the term " *Variabilis* Bank " used by Engel (1894 : 55) has been shown by Ernst (1924, Table facing p. 118) to have its upper limit below that of the Variabilis Zone. The three zones of, successively, *Lillia robusta*, *Harpoceras doerntense* and *Haugia illustris* used by Ernst (1924) and since repeated by Kumm (1941) are together equivalent to the Variabilis Zone.

At Heiligenstein, Alsace, Schirardin (1914 : 343) proposed a " Zone der *Harpoceras bicarinatum* Zieten " which, from its position between what would here be called the Falcifer and Thouarsense Zones, might be considered to be partly equivalent to the Bifrons Zone. The zone was subdivided into two parts, also termed zones, a lower of *Lillia lilli* and an upper of *Haugia variabilis*. The latter appears to contain ammonites of both the Variabilis and Thouarsense Zones, but the former is more difficult to place. Several of the determinations are suspect and include genera normally found as high as the Levesquei Zone, but the large number of Phymatoceratinae recorded suggests that probably nothing more than part of the Variabilis Zone is represented. The Bifrons Zone is probably absent or condensed, and a phosphate bed with fossil débris has been recorded from this point in the succession by Theobald & Maubeuge (1950 : 274).

At Semur Collenot (1869 : 190) used Zones of *Ammonites complanatus*, *Turbo subduplicatus* and *Ammonites mucronatus*, successively overlying the Zone of *Ammonites serpentinus*. It has already been shown (p. 480) that the Zone of *A. complanatus* is equivalent to the present Bifrons Zone, but as the fauna listed (Collenot, 1869 : 199) includes *Ammonites erbaensis* von Hauer (now placed in *Phymatoceras*) the Variabilis Zone may be partly represented, though little is known of the overlap between *Hildoceras* and the Phymatoceratinae in France. The remaining zones of *Turbo subduplicata* and *A. mucronatus* together probably represent nothing higher than the Variabilis Zone as the former horizon contains *Haugia variabilis* (d'Orbigny) and the latter contains *Hammatoceras insigne* (Schübler), *Pseudolioceras lythense* (Young & Bird) and " *Dactylioceras* " *mucronatum* (d'Orbigny).

In France the " Zone à *Harpoceras bicarinatum* " used by Monestier (1921 : 281) at Aveyron occurs below the Thouarsense Zone ; the recorded fauna includes *Haugia*, *Lillia* and " *Dactylioceras* " (? misidentified as *Peronoceras*). South-east of Aveyron the " Zone à *Haugia variabilis* et *Harpoceras bicarinatum* " (Monestier, 1922 : 324) may be equivalent to the Variabilis Zone, but further work is necessary to establish the vertical range of the Phymatoceratinae in this area. At Poitiers the " Zone à *Pseudogrammoceras striatulum* " as used by Gillard (1940 : 601) apparently includes both the Variabilis Zone and the Striatulum Subzone.

## THOUARSENSE ZONE

(Pl. 73, fig. 3)

INDEX SPECIES. *Grammoceras thouarsense* (d'Orbigny, 1844 : 222, pl. 57). An English specimen from the Cotswolds has been figured by Buckman (1928, pl. 774).

NOMENCLATURE. The name was first used by Brasil (1895 : 39) in Normandy as " Niveau de *Grammoceras toarcense* (*sic*) et *G. fallaciosum* ", a term later modified to " Zone à *Grammoceras toarcense* " (Brasil, 1896 : 147). Brasil's faunal list contains *Grammoceras metallarium* (Dumortier), a species now placed in *Phlyseogrammoceras*, and the horizon may therefore include part of the Dispansum Subzone. Welsch (1911 : 9) has used " Zone à *Ammonites toarcensis* " in much the same sense as at present. Synonyms include : *Striatulum*-Beds (Buckman, 1890*a* : 77) ; Bank der *Harpoceras striatulum* (Denckmann, 1893) ; *striatuli* hemera as used by Buckman & Wilson (1896 : 687) ; Zone der *Harpoceras striatulum* (Stolley, 1909). Buckman's (1925 : 75) Grammoceratan Age comprises the Thouarsense Zone together with the overlying Dispansum Subzone.

STRATIGRAPHY. The lower limit of the zone is defined by the sudden appearance of *Grammoceras*, particularly *G. striatulum* (J. de C. Sowerby) and *G. thouarsense*. The two species are closely related and frequently occur together, but in France *G. thouarsense* has also been recorded as coexisting with *Pseudogrammoceras* (s.s.), presumably in the Struckmanni Subzone (Gillard, 1940 : 603), and would appear to be a suitable zonal index, though it is not certain whether it ranges throughout the entire zone. Coincident with the appearance of *Grammoceras* is the disappearance of most of the Phymatoceratinae, at least in Britain, although the group continues upwards into the Striatulum Subzone as *Esericeras eseri* (Oppel), a species which has sometimes been referred to *Haugia*. The upper boundary of the zone is marked by the appearance of *Phlyseogrammoceras*.

### *Striatulum Subzone*

(Pl. 74, fig. 3)

INDEX SPECIES. *Grammoceras striatulum* (J. de C. Sowerby, 1823 : 23, pl. 421, fig. 1). The holotype was refigured by Buckman (1890, pl. 26, figs. 7, 8).

NOMENCLATURE. The name was first used by Hudleston (1874 : 295) as *Striatulus*-Beds, and later, as a subzone of the Jurense Zone, by both Buckman (1888 : 45, 50 ; 1890*a* : 76–80) and Spath (1942 : 265). Synonyms include : *eseri* hemera (Buckman, 1925 : 75) ; Striatulum Zone (Arkell, 1930, Table facing p. 410) ; Eseri Zone (Gillard, 1940 : 602) ; *Toarcensis*-Schichten (Krumbeck, 1943 : 281).

STRATIGRAPHY. The base of the subzone is defined by the appearance of the first *Grammoceras*, and it ends with the incoming of *Pseudogrammoceras*. In the lower part of the Striatulum Shales in Yorkshire the zonal ammonite is accompanied by other species of *Grammoceras*, together with the characteristic *Pleurolytoceras* ? *gubernator* (Simpson). *Pseudolioceras* is fairly common, particularly *P. compactile* (Simpson) for which this is the type horizon. Elsewhere in England the subzone is

found only in the Cotswolds, Somerset and Dorset where it usually occurs either as sandstones, part of the Midford Sands and Cotswolds Sands, or within a condensed sequence. These outcrops contain the only recorded English specimens of *Esericeras eseri* (Oppel), but the species is widely recorded elsewhere in Europe.

In Scotland the Raasay Ironstone of the Hebridean area was at one time thought to belong to the Bifrons Zone (Buckman, 1920 : 67) owing to its containing " *Hildoceras bifrons* (d'Orbigny *non* Bruguière) ", but as the result of additional evidence from the Ardnamurchan district the age was redetermined as " Striatulum Zone " and the Whitbian ammonites which were also present were described as being derived (Buckman *in* Richey & Thomas, 1930 : 43–44). The fossils upon which this claim was founded were obtained from loose blocks of ironstone near Kilchoan, and we are indebted to Mr. R. B. Wilson of the Geological Survey of Scotland for the loan of these specimens. Although no information is available regarding the original position of the fossils within the rock, the ammonites appear to belong to two distinct horizons. The lower is represented mainly by Dactylioceratidae indicating the Bifrons Zone, though no *Hildoceras* is present ; the higher is shown to be Thouarsense Zone by two specimens of *Grammoceras*. The condition of the Dactylioceratidae of the Bifrons Zone suggests that they are indigenous, and not derived as claimed by Buckman. It seems likely that parts of both the Bifrons and Thouarsense Zones are represented, with a stratigraphical break between them occurring within the Ironstone. A further break occurs between the Ironstone and the overlying Dun Caan Shales which belong to the Aalensis Subzone.

In France the " Zone à *Haugia eseri* " used by Gillard (1940 : 602) at Poitiers was said to overlie a " Striatulum Zone ", though the two were difficult to separate in some places. The fauna listed by him includes several Phymatoceratinae, such as *Denckmannia*, *Haugia* and *Phymatoceras*, which are characteristic of the Variabilis Zone, and the sequence may be condensed.

### *Struckmanni Subzone*

(Pl. 74, fig. 1)

Index species. *Pseudogrammoceras struckmanni* (Denckmann, 1887 : 72, pl. 3, fig. 1).

Nomenclature. The name was first used by Buckman (*in* Buckman & Wilson, 1896, footnote to p. 688) to denote a subdivision " 3. *Grammoceras Struckmanni*, and allied species ", and later as *Struckmanni* hemera (Buckman, 1898, Table facing p. 450). Since then the name has been generally used for a subzone of the Jurense Zone (Spath, 1942 : 265). Synonyms include : *dispansi* hemera as used by Buckman & Wilson (1896 : 700) ; *Pedicum* Bed (Richardson, 1910 : 106) ; Pedicum Zone (Buckman, 1912 : *c*) ; Struckmanni Zone (Arkell. 1930, Table facing p. 410) ; Fallaciosum Subzone (Muller, 1941, Table 2) ; *Fallaciosus*-Schichten (Krumbeck, 1943 : 281). The " Zone à *Ammonites insignis* " proposed by Welsch (1911 : 9) at Thouars includes both the Struckmanni and Dispansum Subzones.

Stratigraphy. The base of the subzone is defined by the appearance of *Pseudogrammoceras*, and the top is placed immediately below the first occurrence of *Phlyseo-*

*grammoceras*. *Pseudogrammoceras* has recently been placed in the synonymy of *Grammoceras* (Arkell *in* Arkell, Kummel & Wright, 1957 : L261) but the two are regarded here as being generically distinct ; they are found together in at least the lower part of the subzone. Most of the known British species of *Pseudogrammoceras* have been found in the condensed cephalopod-bed facies of the Cotswolds ; in the upper Striatulum Shales of Yorkshire the genus is uncommon, though *P. latescens* (Simpson) is characteristic (Dean, 1954 : 178). Arkell's (1933 : 171) claim, founded on the record of *Grammoceras fallaciosum*, a species now assigned to *Pseudogrammoceras*, that the Dispansum Subzone is present in Dorset is probably incorrect.

In France, south-east of Aveyron, Monestier (1921 : 283, 285) proposed a " Zone à *Pseudogrammoceras expeditum* Buckman ", overlain by the " Zone à *Polyplectus discoides* Zieten et *Hammatoceras insigne* Schübler ". These two zones are together probably equivalent to all, or part of, the Struckmanni Subzone.

The " Zone à *Grammoceras fallaciosum* " as used at Tournemire by Nicklès (1907 : 579) overlies the Bifrons Zone, the Variabilis Zone apparently being absent, and is in turn overlain by the " Zone à *Dumortieria radiosa* ". The recorded fauna includes *Pseudogrammoceras*, *Paroniceras sternale* (von Buch) and *Polyplectus* (= *Lioceras discoides*), and the zone probably comprises both the Struckmanni and Dispansum Subzones, though *Phlyseogrammoceras* is not recorded.

In Lorraine, Corroy & Gérard (1933) have employed the term " Zone à *Pseudogrammoceras fallaciosum* auct." in a broad sense, probably equivalent to the Striatulum to Dispansum Subzones of the present paper. Their faunal lists show that their successive horizons of *Pseudogrammoceras expeditum* and *Hammatoceras insigne* fall within the Struckmanni Subzone, but their record of *Frechiella subcarinata* (Young & Bird), a characteristic species of the Bifrons Zone, is probably a misidentification of a *Paroniceras*, for *P. sternale* (von Buch) is also recorded.

Although the " Horizon à *Hammatoceras insigne*, *Lytoceras germaini* et *Paroniceras sternale* " proposed by Piroutet (1920 : 21) near Salins, in the Jura, is underlain by strata with " *Grammoceras fallaciosum* " (now *Pseudogrammoceras*) its fauna appears to include both *Grammoceras* and *Pseudogrammoceras*, and the age of the stratum is probably Struckmanni Subzone. Of the supposed zonal indices, *Paroniceras sternale* has a long vertical range and has been recorded by Gillard (1940 : 602–603) from the Striatulum, Struckmanni and Dispansum Subzones. The same writer has distinguished two successive zones of *Pseudogrammoceras pedicum* and *P. struckmanni* at Poitiers (Gillard, 1940 : 603–604), but his faunal list suggests that the two are together equivalent to the present Struckmanni Subzone.

## LEVESQUEI ZONE

(Pl. 73, fig. 5)

INDEX SPECIES. *Dumortieria levesquei* (d'Orbigny, 1844 : 230, pl. 60). Species figured by Roquefort & Daguïn (1929, pl. 22, fig. 5).

NOMENCLATURE. First used by Benecke (1901 : 144, 149) as *Levesquei*-Schichten in the area of Lorraine and Luxemburg. Buckman's Dumortierian Age (1925 : 75), comprising the *Hammatoceras*, *levesquei*, *novata*, *subsolaris*, *Catulloceras* and *moorei*

hemerae, together with the *dispansum* hemera from the preceding Grammoceratan Age, includes the Dispansum to Moorei Subzones inclusive. The *Levesquei*-Schichten of Krumbeck (1943 : 281) include the Levesquei to Aalensis Subzones. The Opalinum Zone as used by Wright (1879 : 163) probably includes the Moorei and Aalensis Subzones in addition to the Opalinum Subzone of the Bajocian, with his Jurense Zone comprising the Variabilis Zone to the Levesquei Subzone inclusive.

Stratigraphy. The base of the zone is defined by the incoming of *Phlyseogrammoceras*, sometimes accompanied by *Dumortieria*, though not in Britain. The appearance of these genera coincides more or less with the extinction of *Pseudogrammoceras*, and the lower and upper limits of the zone mark the maximum recorded vertical range of *Dumortieria*. Three of the four subzones recognized here as constituting the zone are founded on closely-related forms, two species of *Dumortieria* with one of *Pleydellia*. It would have been preferable, if possible, to use another species of *Dumortieria* for the lowest subzone, but the genus is only known from this horizon in a few extra-British areas, whereas *Phlyseogrammoceras dispansum* and allied species are widespread and fairly abundant.

### *Dispansum Subzone*

(Pl. 74, fig. 2)

Index species. *Phlyseogrammoceras dispansum* (Lycett, 1860 : 146). The species was figured for the first time, as *Harpoceras variabilis* var. *dispansum*, by Wright (1882, pl. 67, figs. 3, 4).

Nomenclature. The name was first used by Buckman (1889 : 443) as *Dispansum*-Beds, apparently in the same sense as in the present paper, and has usually been employed as a subzone of the Jurense Zone (Spath, 1942 : 265). Synonyms include : *Hammatoceras* hemera (Buckman & Wilson, 1896 : 688) ; Dispansum Zone (Buckman, 1910 : 88) ; *dispansi* hemera (Buckman, 1910*a* : xvi) ; *Dispansus*-Schichten (Krumbeck, 1943 : 281) ; Sous-zone à *Hammatoceras insigne* (Theobald & Maubeuge, 1950 : 274). The stratigraphical position of the " Zone à *Dumortieria pseudoradiosa* " employed by Brasil (1896 : 147) at Calvados would apparently make it equivalent to the Dispansum to Moorei Subzones inclusive.

Stratigraphy. The appearance of *Phlyseogrammoceras*, particularly *P. dispansum*, defines the base of the subzone, coinciding with the disappearance of *Pseudogrammoceras*. In Yorkshire the genus *Hudlestonia* is most common in this subzone. At one time Buckman (1911 : 210) suggested that in the Cotswolds a *Hudlestonia* horizon might possibly be present between what are now the Dispansum and Levesquei Subzones, but as the sequence there is condensed such a horizon would be difficult to prove and its existence is considered unlikely. *Hudlestonia* has been recorded from the Levesquei and Moorei Subzones of the Cotswolds and Somerset, whilst outside Britain the genus has been found in both the Moorei and Aalensis Subzones by Krumbeck (1943 : 281, 291). According to Denckmann (1897 : 21–22) the horizon of *Hudlestonia affinis* (Seebach), the type-species of the genus, is between the Aalensis and Opalinum Subzones.

The number of other ammonite genera in the British development of the subzone is small and includes only *Alocolytoceras* and *Hammatoceras*, but elsewhere in Europe the horizon marks the earliest appearance of *Dumortieria*. Species definitely recorded from the Dispansum Subzone include *D. insignisimilis* Brauns and *D. striatulocostata* (Quenstedt) in Swabia (Krumbeck, 1943 : 287, 316), but other forms, though recorded, are not specifically identified. Other characteristic ammonites include *Alocolytoceras ? peregrinum* (Simpson) and various species of *Phlyseogrammoceras* such as *P. metallarium* (d'Orbigny), *P. orbignyi* Buckman and *P. dispansiforme* (Wunstorf). Gillard's (1940 : 605) record of *Cotteswoldia distans* Buckman in association with *P. dispansum* at Poitiers probably refers to a species of *Dumortieria*.

To the south-east of Aveyron, Monestier (1921) employed the following four successive zones in the upper portion of the Upper Lias : *Grammoceras striatulum*; *Pseudogrammoceras expeditum*; *Polyplectus discoides* and *Hammatoceras insigne*; *Pseudogrammoceras reynesi* and *Phlyseogrammoceras dispansum*. Several of the ammonites were figured subsequently by Monestier (1921*a*) but many of the generic determinations are suspect and in need of revision. It is possible that the succession of zones and subzones present may not, in fact, range from Striatulum to Dispansum.

### *Levesquei Subzone*

(Pl. 73, fig. 5)

Index species. See Levesquei Zone.

Nomenclature. The name as first used by Benecke (1901 : 149) was a subdivision which included also the equivalent of the Dispansum Subzone. It was first employed in the present sense by Buckman (1925 : 75) as the *levesquei* hemera, and has since been used as a subzone of the Jurense Zone (Spath, 1942 : 265). Synonyms include : *Dumortieria* Zone (Buckman, 1910 : 88 ; Arkell, 1930, Table facing p. 410 ) ; Subzone of *Dumortieria* spp. (Arkell, 1933 : 165) ; *Striatulo-costatus* Lage (Krumbeck, 1943 : 281).

Stratigraphy. In England the base of the subzone is defined by the first appearance of *Dumortieria* which, as far as is known, coincides with the extinction of *Phlyseogrammoceras*. The most fossiliferous English development is found in the Cotswolds, but the sequence there is condensed and exact horizons are difficult to distinguish. In Dorset the subzone is present either condensed, or as sandstones generally similar to those of Yorkshire, where the fauna has not yet been found.

Numerous species, probably too many, of *Dumortieria* have been described and, generally speaking, they can be said to fall into two groups which form the basis of subdivision of the middle portion of the Levesquei Zone. Although exceptional and transitional forms are known, the early species of *Dumortieria* tend to be coarsely ribbed, constituting what Ernst (1924 : 118) called the " *Levesquei*-Gruppe ". The earliest-known species are recorded from the Dispansum Subzone, at which horizon, in North-west Germany, they include *Dumortieria sparsicosta* Haug and *D. munieri* Haug, and in Swabia *D. striatulocostata* (Quenstedt), together with an occasional record of *D. levesquei* itself (Corroy, 1931 : 205 ; Krumbeck, 1943 : 316). The amount of overlap between *Dumortieria* and *Phlyseogrammoceras* is small and individuals

of the former genus become much more numerous after the extinction of the latter. The absence of *Phlyseogrammoceras* is an important factor in defining the base of the Levesquei Subzone, and the upper limit of the subzone is drawn immediately below the first appearance of *Dumortieria moorei* (Lycett) and allied forms. Species which appear to be particularly characteristic of the Levesquei Subzone include *Dumortieria levesquei, D. munieri, D. subsolaris* Buckman, *D. striatulocostata* and *D. prisca* Buckman.

The equivalents of the Levesquei and Moorei Subzones have sometimes been grouped together under one stratigraphical name, and these include : *Dumortieria*-Beds (Buckman & Wilson, 1896 : 707) ; *Dumortieriae* hemera (Buckman & Wilson, 1896 : 677) ; Zone à *Dumortieria radians* (Welsch, 1903 : 821 ; 1911 : 9–10) ; Zone à *Dumortieria* (Roquefort & Daguin, 1929 : 252) ; Subzone of *Dumortieria* spp. (Dean, 1954 : 166) ; and, perhaps, Sous-zone à *Dumortieria radiosa* (Theobald & Maubeuge, 1950 : 274). The " Zone à *Dumortieria radiosa* " used by Nicklès (1907 : 580) at Tournemire may include both the Levesquei and Moorei Subzones, but it is difficult to tell from his description. Another subdivision with *D. radiosa* as index used in Germany by Ernst (1924, Table facing p. 118), who was followed by both Kumm (1941 : 238) and Hoffmann (1949 : 115), apparently includes the Moorei Subzone together with an undetermined upper portion of the Levesquei Subzone. The " Zone à *Dumortieria levesquei* " as used in France, north of the Massif Central, by Mouterde (1953 : 7) is made up of successive horizons of *D. radiosa* (Seebach) and *D. moorei* ; it seems probable that the former, as employed by him, is equivalent to the Levesquei Subzone.

### *Moorei Subzone*

(Pl. 74, fig. 5)

Index species. *Dumortieria moorei* (Lycett, 1857 : 122, pl. 1, fig. 2a. only). Holotype refigured by Wright (1884, pl. 80, figs. 1, 2).

Nomenclature. The name was first used by Buckman (1889 : 443) as *Moorei*-Beds, and later as Moorei Zone (Buckman, 1910 : 88), since which time it has been reduced to a subzone of the Jurense Zone (Spath, 1942 : 265). Synonyms include : Zone à *Dumortieria radiosa* (Schneider, 1927 : 8) ; Moorei Zone (Arkell, 1930, Table facing p. 410) ; *Radiosus*-Schichten (Krumbeck, 1943 : 281). The subzone probably comprises the *novata, subsolaris, Catulloceras* and *moorei* hemerae of Buckman's (1925 : 75) Dumortierian Age.

Stratigraphy. The base of the subzone is defined by the appearance of *Dumortieria moorei*, and the upper limit is drawn below the appearance in force of *Pleydellia aalensis* and allied forms. The latter appear to coincide with the disappearance of *D. moorei*, but other species of *Dumortieria* range upwards and may even include occasional records of coarsely-ribbed forms such as *D. costula* and *D. munieri* which form an uncommon exception to the general rule that the finely-ribbed and striate species are the stratigraphically younger. These records have been encountered in Swabia (Krumbeck, 1943 : 291, 295, 324) but in other areas *Dumortieria* is generally absent from the Aalensis Subzone. Most of the species of *Dumortieria* which are

restricted, or nearly so, to the Moorei Subzone are finely ribbed and belong to the "*Radiosa*-Gruppe" of Ernst (1924 : 118); they include *D. moorei*, *D. radiosa* (Seebach), *D. pseudoradiosa* (Branco), *D. gundershofensis* Buckman and *D. rhodanica* (Haug).

In England the subzone is found in Yorkshire, constituting the uppermost Yellow Beds of the Blea Wyke Sands, and in the Somerset–Dorset and Cotswolds areas where it is present usually either as sandstones, the Ham Hill Stone and part of the Yeovil Sands, or in the condensed sequence of the cephalopod-bed facies. Most of the species of *Pleydellia* described by Buckman from the "Cephalopod-Bed" of the Cotswolds were said originally to have been collected from the Moorei Subzone, but their horizon was subsequently emended to Aalensis Subzone (Buckman, 1904 : cxxxvii–cxxxviii) and the genera *Pleydellia* and *Dumortieria* have yet to be discovered together in Britain. In addition to *Dumortieria*, other ammonites recorded from the Moorei Subzone in Britain include *Phylloceras* [*Xeinophylloceras*] *xeinum* (Buckman) and *Catulloceras* [*Dactylogammites*] *digitatum* (Buckman), the latter genus being found more abundantly in the Aalensis Subzone. Previous records suggest that *Pleurolytoceras leckenbyi* (Lycett) is probably confined to the Moorei and Aalensis Subzones.

On the Continent, in Lorraine, Benecke (1901 : 154) introduced a subdivision termed "Schichten der *Dumortieria subundulata* und des *Lioceras opalinum*", the lowest part of which, "das braune lager", is equivalent to the Moorei Subzone as it contains *D. moorei*, *D. pseudoradiosa* and *D. bleicheri* Benecke. The last-named species has been recorded only from this horizon in Swabia by Krumbeck (1943 : 286).

### *Aalensis Subzone*

(Pl. 74, fig. 4)

INDEX SPECIES. *Pleydellia aalensis* (Zieten, 1832 : 37, pl. 28, fig. 3). An English specimen from the Cotswolds was figured by Buckman (1890, pl. 32, figs. 3–6).

NOMENCLATURE. The name was first used as "Zone à *Ammonites aalensis*" by Reynès (1868 : 68) for strata overlying the Jurense Zone. It was adopted by Buckman (1913 : x) for the English succession as the lowest subdivision of the "Aalenian Stage" and Inferior Oolite. He was followed by Arkell (1933 : 165), but Spath (1942 : 265), following the original definition of Toarcian and Aalenian, rightly retained it in the Toarcian Stage and used it as the topmost subzone of the Jurense Zone. Synonyms are numerous and include : Couches à *Ammonites torulosus* (Mayer-Eymar, 1864); *aalensis* hemera (Buckman & Wilson, 1896 : 677ff.); Zone à *Pleydellia* (Roquefort & Daguin, 1929 : 253); Aalensis Zone (Arkell, 1930, Table facing p. 410); *Hircinus*-Schichten and, probably, *Torulosus*-Schichten (Krumbeck, 1943 : 281, 293); Sous-zone à *Pleydellia aalense* et *Gotteswaldia* (*sic*, misprint of *Cotteswoldia*) *costulata* (Theobald & Maubeuge, 1950 : 274); Zone à *Lytoceras torulosum* (Theobald & Maubeuge, 1950 : 280); Zone à *Canavarina venustula*, Zone à *Gotteswaldia* (*sic*) *spathi*, Zone à *Dumortieria pseudoradiosa*, and Zone à *Pleydellia buckmanni* (Theobald & Maubeuge, 1950 : 282). The whole of Buckman's (1925 : 75) Canavarinan Age, comprising the *Cotteswoldia*, *digna*, *venustula* and *Canavarella* hemerae, is equivalent to the Aalensis Subzone.

STRATIGRAPHY. The base of the subzone is defined by the appearance of *Pleydellia aalensis* and allied species, whilst the top is drawn immediately below the first *Leioceras*. So far as is known the limits of the subzone are generally defined by the vertical range of *Pleydellia* in abundance, though the genus may occasionally range upwards into the basal Bajocian. Although Arkell (*in* Arkell, Kummel & Wright, 1957 : L261) has placed Buckman's genera *Canavarina*, *Canavarella*, *Cotteswoldia* and *Walkericeras* in the synonymy of *Pleydellia*, the names have been frequently employed and given at least subgeneric status, particularly by French palaeontologists. *Walkericeras subglabrum* Buckman has been recorded from the *opaliniforme* hemera of the Hebrides by Buckman (1920 : 66).

In France, north of the Massif Central, Mouterde (1953 : 7) has recognized a horizon of *Pleydellia mactra* (Dumortier) underlying that of *P. aalensis*, but it is doubtful whether such a separation is more than locally applicable and the two species have been recorded together at Thouars (Welsch, 1911 : 10), at Hérault, southern France (Roquefort & Daguin, 1929 : 253), and in Swabia (Krumbeck, 1943 : 294, 297). The ammonites of the " Zone à *Dumortieria moorei* et *Lioceras partitum* ", a subdivision in Lorraine proposed by Gérard & Bichelonne (1940 : 23), have been redescribed by Maubeuge (1946) as species of *Pleydellia* and *Cotteswoldia* belonging to the Aalensis Subzone.

The best development of the subzone in Britain is in the Dun Caan Shales of Raasay, where the ammonite fauna resembles that of the uppermost Yeovil Sands of Crewkerne, Somerset (Arkell, 1933 : 183). It was here that Buckman (1920) first established the *Cotteswoldia, digna* and *venustula* hemerae, horizons which are probably of no more than local significance. The subzone is not developed in Yorkshire, is found condensed in the Cotswolds, and is only thinly developed in Somerset and Dorset, mainly as the topmost Yeovil and Bridport Sands together with thin, overlying clays and limestones. *Pleurolytoceras hircinum* (Schlotheim) is widespread at this horizon and may be restricted to it. *Pleydellia* and *Dumortieria* are generally found at separate horizons but have been recorded together in Swabia (Krumbeck, 1943 : 294, 302), and in France north-east of the Massif Central (Mouterde, 1953 : 365).

## VIII. INDEX TO STAGES, ZONES, SUBZONES AND HEMERAE

All generic and specific names which have been used as indices for zones, subzones, hemerae, horizons and beds are included. References to accepted zonal and subzonal indices are in **bold** type.

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## PLATE 63

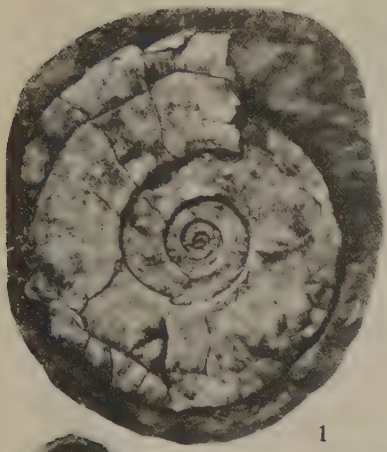
FIG. 1. *Psiloceras planorbis* (J. de C. Sowerby). Watchet, Somerset. Lectotype, figured by J. de C. Sowerby, 1824, pl. 448, upper figure. BM. 43875. × 1.

FIG. 2. *Psiloceras* (*Caloceras*) *johnstoni* (J. de C. Sowerby). Watchet, Somerset. BM. 67976. × ¾.

FIG. 3. *Alsatites liasicus* (d'Orbigny). Pouilly, Côte d'Or. Lectotype, figured by d'Orbigny, 1844, pl. 48, and by Reynès, 1879, pl. 6, figs. 9–12. Muséum d'Histoire naturelle, Paris, coll. d'Orbigny 1441. × ⅔.

FIG. 4. *Schlotheimia* (*Waehneroceras*) *portlocki* (Wright). Kaye's Quarry, Stockton, Warwickshire. BM. C8555. × ¾.

FIG. 5. *Alsatites laqueus* (Quenstedt). Bebenhausen, Württemberg. Holotype, figured by Quenstedt, 1856, pl. 3, fig. 5. Geol.-Pal. Institut, Tübingen, Ce 5/1/14. × 1.



1

2

3b

3a

4a

4b

5b

5a

HETTANGIAN ZONAL AMMONITES

## PLATE 64

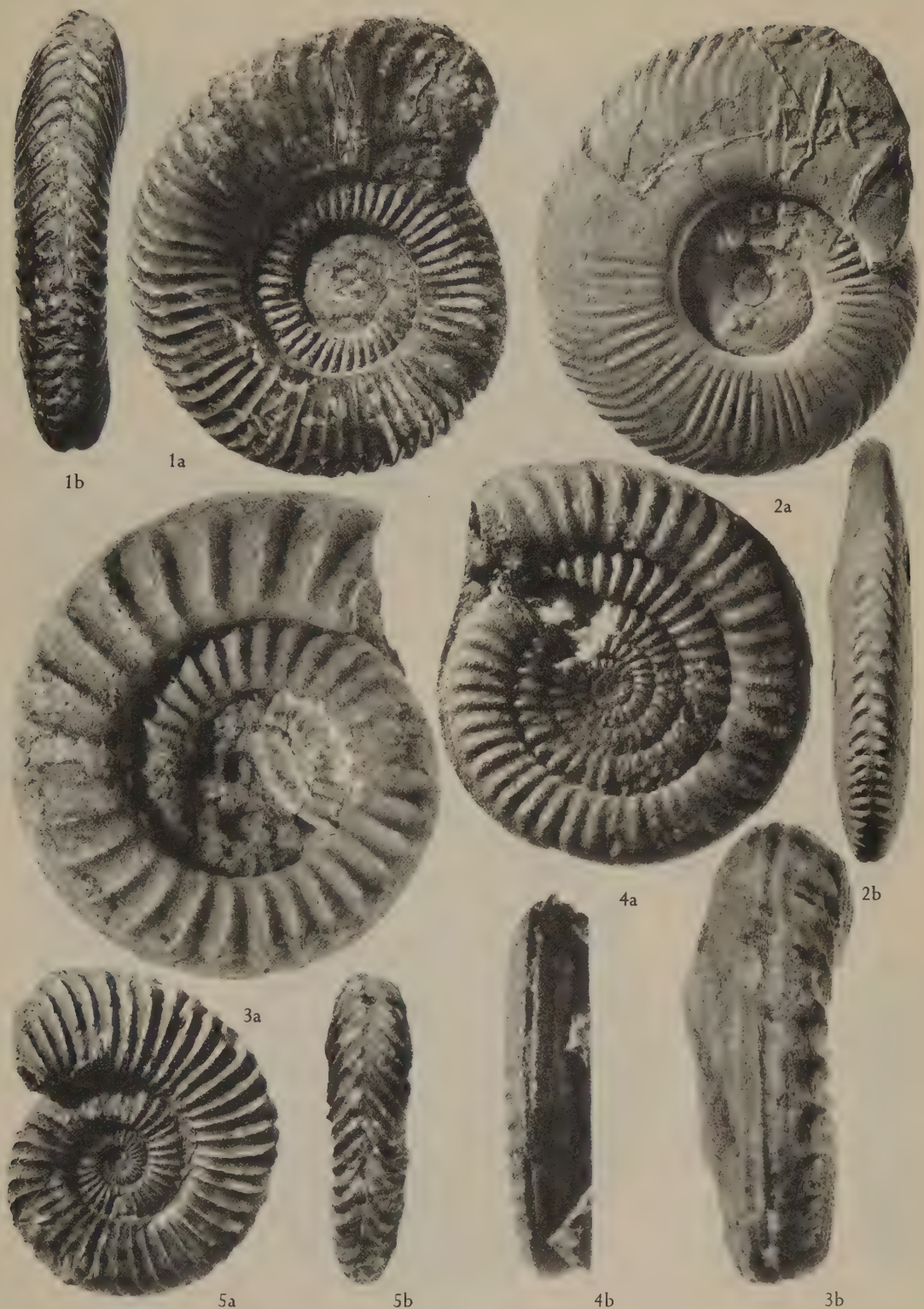
FIG. 1. *Schlotheimia extranodosa* (Waehner). Herford, Westphalia. BM. C31408. × 1.

FIG. 2. *Schlotheimia complanata* von Koenen. Osterwald, Westphalia. Holotype, figured by von Koenen, 1902 : 9, pl. 7, figs. 4–6. Geologisches Institut, Göttingen, 192. × 1.

FIG. 3. *Arietites bucklandi* (J. Sowerby). Manor Road Quarry, Keynsham, Somerset. Bristol University, Geology Dept., 208. × ½.

FIG. 4. *Coroniceras* (*Metophioceras*) *conybeari* (J. Sowerby). Near Bath, Somerset. Holotype, figured by J. Sowerby, 1816, pl. 131. BM. 43971. × ⅔.

FIG. 5. *Schlotheimia angulata* (Schlotheim). Strasdorf, Württemberg. BM. C1408. × 1.




HETTANGIAN AND LOWER SINEMURIAN ZONAL AMMONITES

## PLATE 65

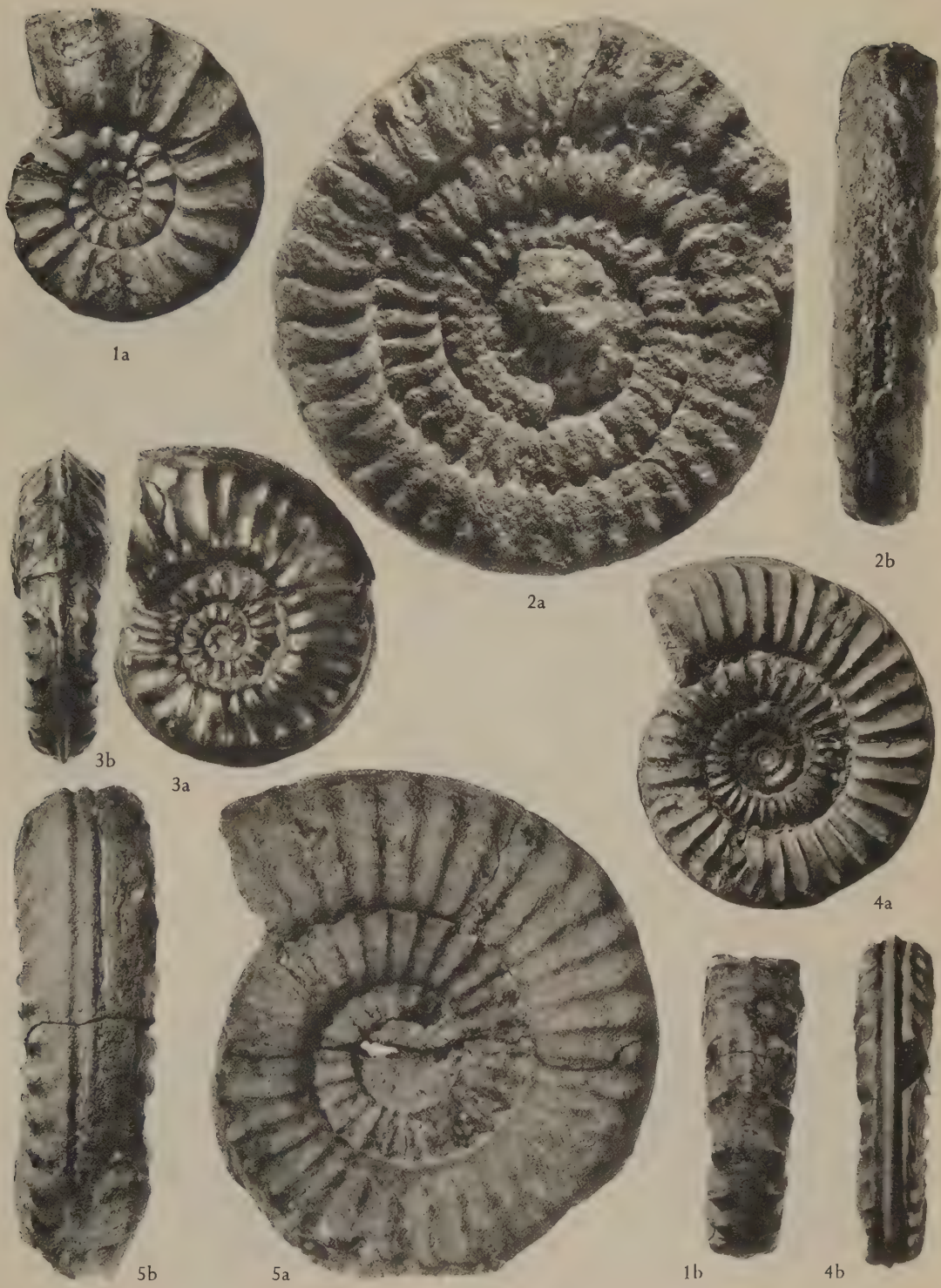
FIG. 1. *Euagassiceras sauzeanum* (d'Orbigny). Gloucestershire. BM. 39586. × 1.

FIG. 2. *Coroniceras rotiforme* (J. de C. Sowerby). Near Yeovil, Somerset. Holotype, figured by J. de C. Sowerby, 1824 : 76, pl. 453. BM. 43975. × ½.

FIG. 3. *Agassiceras scipionianum* (d'Orbigny). Robin Hood's Bay, near Whitby, Yorkshire. BM. 37909. × 1.

FIG. 4. *Arnioceras semicostatum* (Young & Bird). Robin Hood's Bay, near Whitby, Yorkshire. Referred to by Spath, 1923 : 70. BM. C25651. × 1.

FIG. 5. *Coroniceras reynesi* (Spath). Pittsville, Keynsham, Somerset. Bristol University, Geology Dept., 211. × ⅔.




LOWER SINEMURIAN ZONAL AMMONITES

## PLATE 66

FIG. 1. *Caenisites brooki* (J. Sowerby). Charmouth, Dorset. BM. C56066. × ¾.

FIG. 2. *Caenisites turneri* (J. de C. Sowerby). Bredon Hill, Worcestershire. BM. 67979. × 1.

FIG. 3. *Microderoceras birchi* (J. Sowerby). Charmouth, Dorset. BM. 67973. × 1.

FIG. 4. *Eparietites denotatus* (Simpson). Robin Hood's Bay, near Whitby, Yorkshire. Figured (as *Eparietites impendens* (Young & Bird)) by Tate & Blake, 1876 : 290, pl. 6, fig. 7. BM. C17936. × 1.

FIG. 5. *Oxynoticeras oxynotum* (Quenstedt). Schömberg, Württemberg. Holotype, figured by Quenstedt, 1845 : 98, pl. 5, fig. 11, and Quenstedt, 1884 : 175, pl. 22, fig. 29. Geol.-Pal. Institut, Tübingen, Ce 5/22/29. × 1.


LOWER AND UPPER SINEMURIAN ZONAL AMMONITES

## PLATE 67

FIG. 1. *Asteroceras obtusum* (J. Sowerby). Charmouth, Dorset. BM. C56065. × $\frac{5}{8}$.

FIG. 2. *Asteroceras stellare* (J. Sowerby). Lyme Regis [Charmouth], Dorset. Lectotype, figured by J. Sowerby, 1815 : 211, pl. 93. BM. 43969*a*. × 1.

FIG. 3. *Oxynoticeras oxynotum* (Quenstedt). Cheltenham, Gloucestershire. BM. 37794. × $\frac{3}{4}$.

FIG. 4. *Oxynoticeras simpsoni* (Simpson). Robin Hood's Bay, near Whitby, Yorkshire. Figured by Tate & Blake, 1876 : 291, pl. 8, fig. 4. BM. C17903. × $\frac{3}{4}$.

FIG. 5. *Crucilobiceras densinodulum* Buckman. Charmouth, Doreset. BM. 24177. × 1.

FIG. 6. *Leptechioceras macdonnelli* (Portlock). [Larne, Co. Antrim, Ireland]. Figured by Buckman, 1923, pl. 443. BM. C41756. × 1.


UPPER SINEMURIAN ZONAL AMMONITES

## PLATE 68

FIG. 1. *Echioceras raricostatum* (Zieten). Radstock, Somerset. BM. C56064. × ¾.

FIG. 2. *Paltechioceras aplanatum* (Hyatt). Robin Hood's Bay, near Whitby, Yorkshire. BM. 37999. × ¾.

FIG. 3. *Uptonia jamesoni* (J. de C. Sowerby). Mungar, near Radstock, Somerset. Figured by Wright, 1882 : 352, pl. 51, figs. 1, 2. BM. C2207. × ½.

FIG. 4. *Polymorphites polymorphus* (Quenstedt). Gloucestershire. BM. C50549. Figs. 4*a*, *b*, × 1 ; figs. 4*c*, *d*, × 1½.

FIG. 5. *Phricodoceras* aff. *taylori* (J. de C. Sowerby). Robin Hood's Bay, near Whitby, Yorkshire. BM. C17981. × 1. This species cannot be properly interpreted until the holotype is found or a neotype designated ; the holotype is known to have been presented to the Norwich Museum, but at present it cannot be found.


UPPER SINEMURIAN AND LOWER PLIENSBACHIAN ZONAL AMMONITES

## PLATE 69

FIG. 1. *Platypleuroceras brevispina* (J. de C. Sowerby). Pabba, Inner Hebrides, Scotland. Holotype, figured by J. de C. Sowerby, 1827 : 106, pl. 556, fig. 1. BM. 43915. × 1.

FIG. 2. *Tropidoceras masseanum* (d'Orbigny). Vallée de Saint-Pierre, near Saint-Amand, Cher. Holotype, figured in part by d'Orbigny, 1844 : 225, pl. 58. Muséum d'Histoire naturelle, Paris, coll. d'Orbigny 1643. × 1.

FIG. 3. *Androgynoceras capricornus* (Schlotheim). Amberg, Bavaria. Lectotype, described by Schlotheim, 1820 : 71. Geol.-Pal. Institut und Museum, Berlin University, Schlotheim Coll. × 1.

FIG. 4. *Tragophylloceras ibex* (Quenstedt). Watford, Northamptonshire. BM. C56638. × 1.

FIG. 5. *Acanthopleuroceras valdani* (d'Orbigny). Branch Huish, Radstock, Somerset. Figured by Neaverson, 1928 : 335. BM. C41764. × 1.

FIG. 6. *Beaniceras luridum* (Simpson). Robin Hood's Bay, near Whitby, Yorkshire. Holotype, described by Simpson, 1855 : 46 ; figured by Buckman, 1913, pl. 73. Sedgwick Museum, Cambridge, J3274. × 1.


LOWER PLIENSBACHIAN ZONAL AMMONITES

## PLATE 70

FIG. 1. *Prodactylioceras davoei* (J. Sowerby). Charmouth, Dorset. Referred to by Spath 1936 : 442. BM. 39892. × ¾.

FIG. 2. *Amaltheus stokesi* (J. Sowerby). Eype Mouth, near Bridport, Dorset. Holotype, figured by J. Sowerby, 1818 : 205, pl. 191. University Museum, Oxford, J2248. × ⅝.

FIG. 3. *Amaltheus margaritatus* de Montfort. Sandford, Dorset. BM. C6421. × ¾.

FIG. 4. *Androgynoceras maculatum* (Young & Bird). Robin Hood's Bay, near Whitby, Yorkshire. Figured by Spath, 1938 : 130, pl. 20, fig. 6. BM. C17752. × 1.

FIG. 5. *Oistoceras figulinum* (Simpson). Charmouth, Dorset. Figured by Spath, 1938 : 162, pl. 22, fig. 2. BM. 23862. × 1.


LOWER AND UPPER PLIENSBACHIAN ZONAL AMMONITES

## PLATE 71

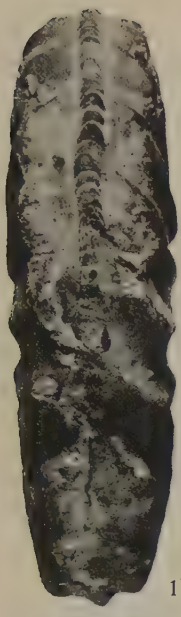
FIG. 1. *Pleuroceras spinatum* (Bruguière). South Petherton, Somerset. Neotype, figured by Howarth, 1958 : 36, pl. 7, fig. 2. Sedgwick Museum, Cambridge, J35923. × ⅔.

FIG. 2. *Amaltheus gibbosus* (Schlotheim). Württemberg. BM. 50083. × 1.

FIG. 3. *Amaltheus subnodosus* (Young & Bird). Hawsker Bottoms, Robin Hood's Bay, near Whitby, Yorkshire. BM. C18073. × 1.

FIG. 4. *Pleuroceras hawskerense* (Young & Bird). Kettleness, near Whitby, Yorkshire. Figured by Howarth, 1958 : 45, pl. 9, fig. 5. Sedgwick Museum, Cambridge, J44296. × 1.

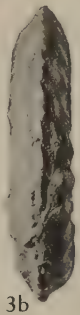
FIG. 5. *Pleuroceras apyrenum* (Buckman). Eston Ironstone Mines, Yorkshire. Holotype, figured by Tate & Blake, 1876 : 295, pl. 8, fig. 2, and by Howarth, 1958 : 35, pl. 6, fig. 1. Geological Survey & Museum, London, 24855. × 1.



1b

1a

2a



3b

2b

4b

3a

5a

5b

4a

UPPER PLIENSBACHIAN ZONAL AMMONITES

## PLATE 72

FIG. 1. *Dactylioceras tenuicostatum* (Young & Bird). Near Whitby, Yorkshire. BM. 14719. × 1.

FIG. 2. *Harpoceras exaratum* (Young & Bird). Whitby, Yorkshire. BM. C2201. × ¾.

FIG. 3. *Harpoceras falcifer* (J. Sowerby). Ilminster, Somerset. Holotype, figured by J. Sowerby, 1820 : 99, pl. 254, fig. 2. BM. 43946. × 1.

FIG. 4. *Hildoceras bifrons* (Bruguière). Whitby, Yorkshire. Figured by Buckman, 1918*a*, pl. 114. This specimen may be the holotype for it matches closely the description and figure of Lister (1678 : 205, pl. 6, fig. 2). BM. C55840. × 1.

FIG. 5. *Dactylioceras commune* (J. Sowerby). Whitby, Yorkshire. Lectotype, figured by J. Sowerby, 1815 : 10, pl. 107, fig. 2. BM. 43895*a*. × 1.

1b

1a

2a

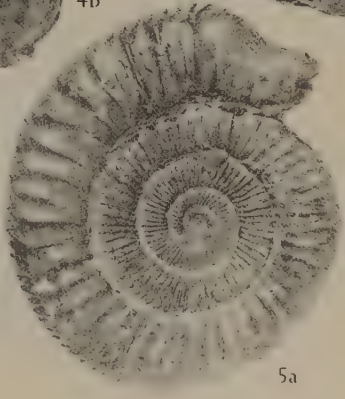
3a

4b

4a

3b

2b



5a

5b

LOWER TOARCIAN ZONAL AMMONITES

## PLATE 73

FIG. 1. *Zugodactylites braunianus* (d'Orbigny). Heyford, Northamptonshire. BM. C56067. × 1.

FIG. 2. *Peronoceras fibulatum* (J. de C. Sowerby). Whitby, Yorkshire. Holotype, figured by J. de C. Sowerby, 1823 : 147, pl. 407, fig. 2. BM. 43911. × 1.

FIG. 3. *Grammoceras thouarsense* (d'Orbigny). Thouars, Deux Sèvres. BM. C7384. × 1.

FIG. 4. *Haugia variabilis* (d'Orbigny). Amayé sur Orne, Calvados. BM. 37195. × ¾.

FIG. 5. *Dumortieria levesquei* (d'Orbigny). Wotton-under-Edge, Gloucestershire. Bristol University, Geology Dept., 11425. × 1.

1b

1a

2a

2b

3b

3a

4a

4b

5a

5b

LOWER AND UPPER TOARCIAN ZONAL AMMONITES

## PLATE 74

FIG. 1. *Pseudogrammoceras struckmanni* (Denckmann). Gmünd, Württemberg. BM. C1309. × ¾.

FIG. 2. *Phlyseogrammoceras dispansum* (Lycett). Frocester Hill, near Stroud, Gloucestershire. Figured by Wright, 1882, pl. 67, figs. 3, 4. BM. C1860. × ¾.

FIG. 3. *Grammoceras striatulum* (J. de C. Sowerby). Peak, Ravenscar, Yorkshire. Figured by Buckman, 1890 : 173, pl. 26, figs. 7–10. (This specimen is not the holotype which is lost.) BM. 43953. × 1.

FIG. 4. *Pleydellia aalensis* (Zieten). Hazelbury Mills, Somerset. Geological Survey & Museum, London, 69983. × 1.

FIG. 5. *Dumortieria moorei* (Lycett). Frocester Hill, near Stroud, Gloucestershire. Holotype, figured by Lycett, 1857 : 122, pl. 1, fig. 2*a*, and by Wright, 1884 : 458, pl. 80, figs. 1, 2. Geological Survey & Museum, London, 25312. × ¾.


UPPER TOARCIAN ZONAL AMMONITES

## PLATE 75

Outcrops of the Lias in the North-west European Liassic Ammonite Province. The heavy broken line marks the southern and eastern boundary of the Province.


Miles
0 50 100 200
NORTH SEA
SKYE
RAASAY
EDINBURGH
BELFAST
CARLISLE
WHITBY
LINCOLN
SHREWSBURY
Midlands
GLOUCESTER
Cotswolds
LONDON
LYME REGIS
KØBENHAVN
HANNOVER
BRUXELLES
Ardennes
LUXEMBOURG
FRANKFURT
NÜRNBERG
Fränkischer Jura
CAEN
PARIS
PARIS BASIN
NANCY
STRASBOURG
STUTTGART
Vosges
Black Forest
Swäbischer Jura
AVALLON
DIJON
BASEL
ZÜRICH
POITIERS
JURA
LAKE GENEVA
MASSIF CENTRAL
LYON
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MILANO
TORINO
GRENOBLE
Aveyron
AVIGNON
FIRENZE
TOULOUSE
MARSEILLE
PYRENEES

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